No. 5

JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF ENERGY, ISLAMIC REPUBLIC OF IRAN

THE STUDY ON EVALUATION OF ENVIRONMENTAL IMPACT OF THERMAL POWER PLANTS IN ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

DECEMBER 1999

SUURI-KEIKAKU CO., LTD.

TOKYO ELECTRIC POWER ENVIRONMENTAL ENGINEERING CO., INC.

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PREFACE

In response to the request from the Government of the Islamic Republic of Iran, the Government of Japan decided to conduct the Study on Evaluation of Environmental Impact of Thermal Power Plants in the Islamic Republic of Iran and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent a study team, led by Mr. Masaaki Noguchi of Suuri Keikaku Co., Ltd. (SUR) and organized by SUR and Tokyo Electric Power Environmental Engineering Co., Inc. to the Islamic Republic of Iran, six times from December 1996 to September 1999.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Iran, and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the promotion of the results of the Study and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Iran for their close cooperation throughout the study.

December 1999

Kimio Fujita

Kimio Fujita
President
Japan International Cooperation Agency

December 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir:

We have pleasure of submitting to you the Final Report of the Study on Evaluation of Environmental Impact of Thermal Power Plants in the Islamic Republic of Iran. This report presents the monitored and evaluated influences on ambient air of the regions within 20 km of the two thermal power plants located individually in Tabriz and Esfahan, and also proposes required actions drawn from the evaluation.

This report consists of separated volumes of the summary, the main, and the supporting appendices. The summary volume gives essences of the study results, and the main volume contains explanations all the methods employed, results obtained and recommendations drawn. The supporting appendices compiled from details of employed equipment and methods, individual data, description of transferred technologies, background information, and the like.

On this occasion, we would like to express our deep appreciation and sincere gratitude to all those who extended their kind assistance and cooperation to the Study, in particular to the officials concerned of your agency, Ministry of Foreign Affairs, Ministry of International Trades and Industries, and Embassy of Japan, and also Iranian officials concerned of Ministry of Energy, our counterparts under the Deputy Minister for Energy Affairs and people in the two thermal power plants.

We hope this report will contribute to the solution of environmental issues in Iranian thermal power plants and to the development of the Islamic Republic of Iran.

Sincerely yours,

Masaaki Noguchi
Supervisor, the JICA Study Team

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List of Abbreviation

Az	Code of Iranian Residual Fuel Oil
BOD	Biological oxygen demands
BS	Particulates having aerodynamic diameter less than 4.5 μm
Bz	Code of Iranian Residual Fuel Oil
COD	Chemical oxygen demands
deg C	Centigrade temperature difference
DF/R	Draft Final Report
DST	Iranian Daylight Saving Time
DO	Dissolved oxygen
DOE	Department of Environment in the Iranian President's Office
ED-MOE	Environmental Department in the organization of the Deputy of Energy Affairs, MOE
EHC	Iranian Environmental High Council
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
Fig.	Figure or Figures
F/R	Final Report
GDP	Gross Domestic Product
GNP	Gross National Product
ICES	Iranian Center for Energy Studies
IC/R	Inception Report
I. R. Iran	Islamic Republic of Iran
IT/R	Interim Report
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
MOE	Iranian Ministry of Energy
MW	Mega Watt
NG	Natural Gas: NGL - Natural Gas Liquid, LNG - Liquefied NG
NIOC	National Iranian Oil Company
NOx	Mixture of mainly Nitrogen oxide (NO) and Nitrogen dioxide (NO_2)
OJT	On the Job Training
PG/R	Progress Report
PM	Particulates emitted from sources (include soot from stacks)
ppb	Parts per billion
ppm	Parts per million
PTIO	2-phenyl-4,4,5,5-tetramethylimidazoline-3-oxide-1-oxyl (used for passive samplers)
Rls.	Iranian Currency Unit (Rials); in this Report U.S. $ 1.00 = Rls. 8,000
SOx	Mixture of sulfur dioxide (SO_2) and sulfur trioxide (SO_3)
SPM	Suspended Particulate Matter in air
SS	Suspended solid in water
TEA	Tri-ethanol-amine (used for passive samplers)
TSP	Total Suspended Particulate in air
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
U.S. EPA	Environmental Protection Agency of the United States
WHO	World Health Organization
¥	Japanese Currency Unit; in this Report U.S.$ 1.00 = ¥120
#	Leading mark of numbers listed in REFERENCES in this Report

CHAPTER 1 INTRODUCTION

1.1 Background

This is the Final Report of the Study on Evaluation of Environmental Impact of Thermal Power Plants in Islamic Republic of Iran (the Study).

The Ministry of Energy of I. R. Iran solicited technical cooperation from the Government of Japan in evaluation of environmental effects of power plants in north and northwestern areas of the country, originally in 1994 and subsequently in October 1995. In response to this request, the Japan International Cooperation Agency (JICA), appointed by the Japanese Government as an executing agency, surveyed the Iranian situation as the preparatory step and concluded with the Iranian Ministry of Energy (MOE) the Scope of Work of the project in August 1996 as presented in **Appendices 1-1 and 1-2**. The targeted power plants were squeezed into Tabriz and Esfahan. The executing agency in Iran was the Environment Department in the Energy Planning Office of Deputy Minister for Energy Affairs in the Ministry of Energy.

JICA appointed for the full scale study a team composed of members from the private sector in November 1996 (the JICA Study Team or simply the JICA Team). The Iranian side had also organized its Study Team (the Iranian Study Team or the Counterpart Team) from the members of the executing agency.

This Report is composed of the Summary, the Main Report, and the Supporting Appendices which includes documents, data (except voluminous outputs of local computers at weather and ambient air monitoring stations), methodologies, and the likes, all prepared for the Study. Quoted sources of data, literature, and information other than those generated in the Study are identified in the Report with a mark of # and number in parentheses. The number is listed in the References section of the Main Report.

1.2 Study Overviews

(1) Objectives

The objectives of the Study were:

a) to contribute MOE to increase its own capability for preparation of EIA on existing and planned thermal power plants, for implementation of mitigation plans, for preparation of efficiency improvement plans of the studied power plants, and for other related tasks,

b) to measure current environmental characteristics of existing thermal power plants and their surrounding areas, to evaluate their ambient qualities and to propose mitigation plans and to formulate frames of EIA procedures in consideration of current Iranian conditions, and

c) to transfer relevant technologies to Iranian people through site work, seminars etc. in the course of the Study.

(2) Studied Areas and Pollutants

The Study was focused to the following two power plants, Tabriz and Esfahan, and their surrounding areas of 20 km in radius (**Figs.1.2.1 and 1.2.2**). The characteristics of the two plants are given in **Table 1.2.1.** There is no expansion plan in either Tabriz or Esfahan. Pollutants to be studied were sulfur oxides (SOx), nitrogen oxides (NOx), and particulates. Also analyzed were vanadium, nickel, lead, and zinc as heavy metals in particulates.

Table 1.2.1 Power Plants in the Study

Plant	Unit	Rated MW	Fuel Burnt		Stack (m)		Start-up	Remarks
			Name	S %	H	D		
Tabriz	1*1)	368	Fuel Oil	3.0*2)	120	5.0	1986	two stacks in one 12m shield,
	2*1)	368	ditto	ditto	120	5.0	1988	15% of flue gas re-circulation
Esfahan	1	37.5	Gas Oil &		25	1.5	1969	two stacks in one shield
	2	37.5	Natural Gas		25	1.5	1969	
	3*1)	120	Fuel oil	3.5*3)	55	2.5	1974	Fuel oil only in winter
	4*1)	320	&	3.5	80	5.0	1980	ditto
	5*1)	320	Natural Gas	3.5	80	5.0	1988	ditto

Note: *1) - Stack gases measured in the Study.
*2) - 5 samples from June 1994 to May 1995 showed 1.8~2.1% (#56).
*3) - Analyzed data were 3.0 and 3.13% (#08)

(3) Features of Targeted Areas

A) Tabriz

Tabriz power plant is in Tabriz City (population 1,088,000), the capital of Azarbayjan East Province. Major industrial products are carpets, tractors, etc.

The power plant locates 15 km to southwest from the city and in a plain of 1350 m altitude. South-east of the target area is mountainous sloped to 2200 m altitude and all other area is almost flat with agricultural and fruit production. In winter the area is cold and often thick with snow, while in summer it is hot. Spring and autumn are pleasant.

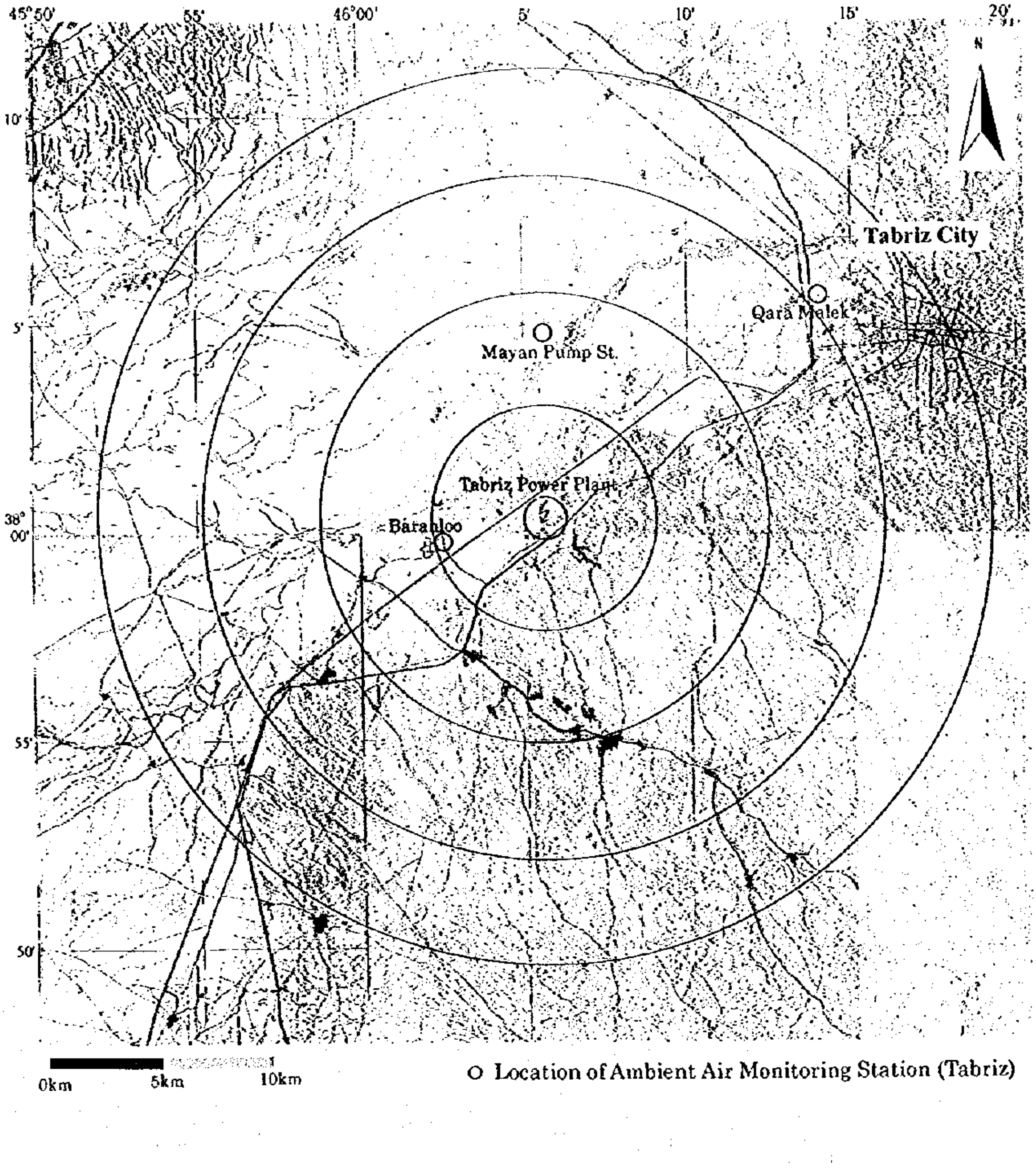


Fig. 1.2.1 Tabriz Thermal Power Plant and its Surrounding Area

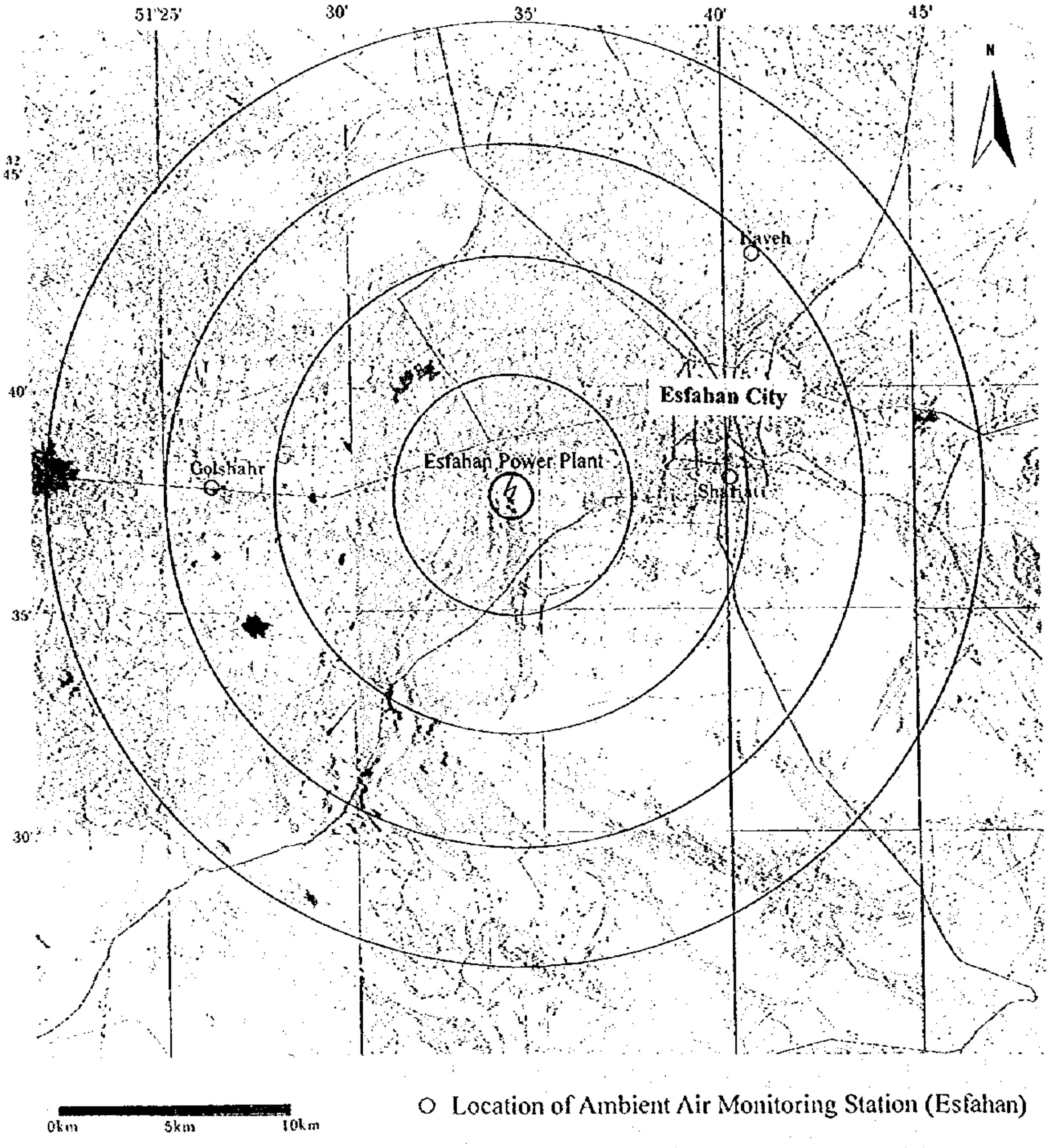


Fig. 1.2.2 Esfahan Thermal Power Plant and its Surrounding Area

Tabriz Refinery (Crude oil 100,000 barrels/day), and Petrochemical Complex of total 250,000 tons annual production are situated at 9 km northeast of the plant.

There is Lake Orumiye 80 km to the west from Tabriz. It is salty and the largest inside lake (4700 km^2, 5 m depth) in Iran. Kandovan, 50 km to the south from Tabriz, has a spring of pristine water and people live in caves of needled rocks similar to Cappadocia of Turkey.

B) Esfahan

Esfahan power plant locates in the Esfahan City (population 1,127,000), the capital of Esfahan Province. The city has many historical monuments and attracts many tourists.

The power plant locates 9 km to southwest from the city. The Zayandeh-Rud river flows along the power plant site. In geographical features around the power plant, North, Northeast, and West of the plant are around 100m - 300m altitude hills and on the other side the slope of one hill is a residential and commercial area. The area has mild weather of four seasons and it snows in winter.

Outside of the area in the north, there is Shahid M. Montazeri Power Plant having total capacity of 800 MW in operation and additional 800 MW under construction. Near the Montazeri Power Plant, located is Esfahan Refinery having a crude capacity of 400,000 barrels/day which supplies fuel oil and natural gas to both Esfahan and Montazeri power plants. At one corner of the Refinery, there is the aromatic complex producing benzene, toluene, etc., of total 160,000 tons per year.

Also outside of the limit, on the south there is the new Mobarakeh Steel Complex (annual steel production of 2,400,000 tons), and on south-west there is the oldest iron producer in Iran, Esfahan Steel Mill established 1971, which is now expanding its blast furnace capacity to 1,900,000 tons annually.

(4) Study Teams

Members of the JICA Study and the Iranian Counterpart Teams and their particular roles are listed in **Tables 1.2.2 and 1.2.3** respectively.

During the Field Work, people from the two power plants were available for monitoring, observation, and other field tasks **(Table 1.2.4)**.

Table 1.2.2 JICA Study Team

	NAME	MAJOR ROLES
1	Masaaki Noguchi	Supervision
2	Takeo Akizawa	Assistant Supervision, Mitigation Plan including Energy Saving, Investigation of Generating Plants
3	Ritsuo Kubota	Air Quality Monitoring, Meteorology Observation, Their Planning
4	Yoshifumi Zama	Stack Gas Monitoring, Its Planning
5	Makoto Miyakawa	EIA Formulation (air, based on the Study Results)
6	Hachiro Yamamoto	EIA Formulation (water, soil, etc.)
7	Yoshio Yamanaka	Investigation of Institutional Aspects
8	Mamoru Yanagihara	Chemical Analysis, Air Quality Monitoring
9	Akeo Fukayama	Numerical Analysis and Diffusion Simulation
10	Osami Kanda	Air Quality Monitoring, Meteorology Observation
11	Ryo Kodama	Upper Layer Observation

Table 1.2.3 Iranian Counterpart Team

	NAME	MAJOR ROLES
1	Abdul Reza Karbassi, Dr.	General Supervision, Mitigation Plan, Energy Saving, EIA, and Institutional & Legal Aspect
2	Bahman Jabbarian Amiri	Project Coordination, and EIA
3	Forood Azari Dehkorodi	Stack Gas Monitoring and Its Planning
4	Hossein Yousefi	Data Management & Simulation, and EIA
5	Reza Samadi	Ambient Air Monitoring and Its Planning, including Meteorology (upper layer) and Simple Air Samplers, Data management & Simulation, and EIA
6	Nastaran Rahimi	Upper Layer Observation and Chemical Analysis
7	Teeka Sohrab	Chemical Analysis

Table 1.2.4 Iranian Local Cooperator

	Tabriz	Esfahan
Coordination	Mohsen Shadravan	Pour Ranjbar*, S.Goodarzy**
Air Monitoring	Hosein Sadeghi, Davod Hakim, Jafar Najafzadeh	P.Ranjbar*, Bahram Qasemi** Mohammad Reza Jebeli
Stack Monitoring	Haji Hasani**, Mehrdad Baibordi Davod Hakim*	Sattar Goodarzy, Abbass Qahramani**
Simple Air Sampling	Mehrdad Baibordi*, J.Najafzadeh**	Pour Ranjbar*, M.R.Jebeli
Plant Lab Work	Ali Asgar Habibi	Sattar Goodarzy
Upper Layer Observ.	Mahrdad Baibordi, Jafar Najafzadeh**	S.Goodarzy, Gholam Reza Fooladi, Gholam Reza Aghakhani**

Note: marked with *- for the Second Field Work only; **- from the Third Field Work

(5) Study Outline

The Study work is given in **Fig. 1.2.3**. It was divided by periodical stages into four analytical and six field ones. **Table 1.2.5** lists the major tasks accomplished in each stage. Analytical work devoted mostly to analyses, compilation, and evaluation of data and information collected in the field work. For collection of data, the JICA Equipment as in **Appendix 1-3** was mainly used during the field work. **Appendix 1-4** is for mothball instruction of the Equipment to be used in other places. Because of substantial delay of purchase, transportation and custom clearance of the JICA Equipment, the Study's schedule was elongated accordingly for about 5 months. **Table 1.2.6** shows the overall time schedule actually consumed for the Study.

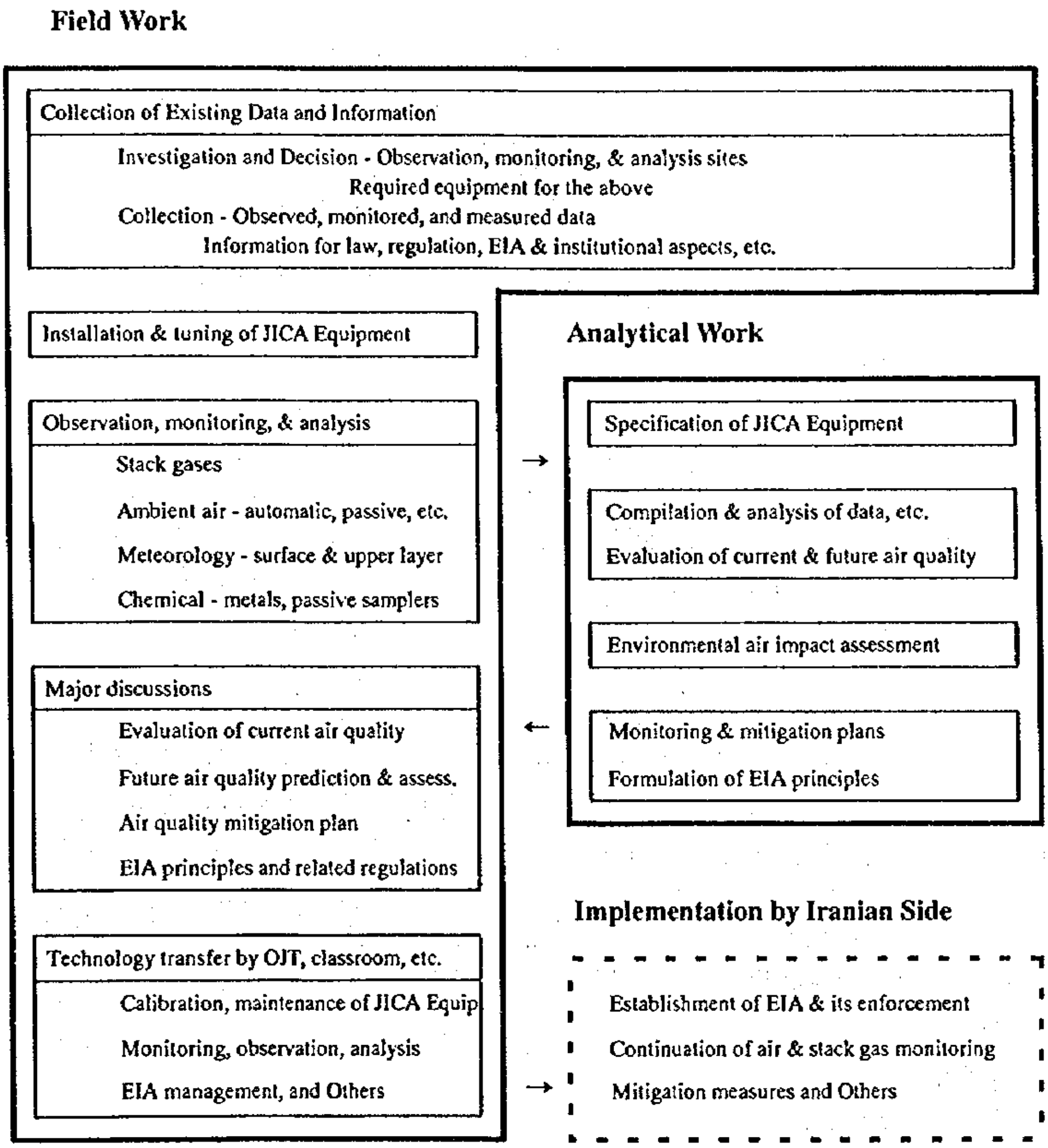


Fig. 1.2.3 Outline of the Study

Table 1.2.5 Work Stages and Tasks

Divided Work Stages (Schedule)	Major Tasks during the Stage
1) First Field Work (12/96 to 1/97)	Discussion of IC/R and collection of data & others
2) First Analytical Work (1 to 2/97)	Preparation of the JICA Equipment specification
3) Second Field Work (1 to 3/98)	Custom clearance and installation of JICA Equipment, commencement of monitoring, observation & analysis (except SOx and NOx monitoring in air and stack gases by automated instrument)
4) Second Analytical Work (2 to 3/98)	Data analyses and EIA formulation study
5) Third Field Work (5 to 7/98)	Commencement of SOx and NOx monitoring in ambient air and stack gases by automated analyzers, and assurance of monitoring, etc.
6) Third Analytical Work (7 to 9/98 and 2/99)	Preparation of IT/R, and preliminary simulation modeling in 2/1999
7) Fourth Field Work (9/98)	Discussion on IT/R
8) Fifth Field Work (2 to 3/99)	Checking of the JICA Equipment conditions and installation of the preliminary simulation model
9) Fourth Analytical Work (5 to 7/99)	Final. of simulation model & DF/R Preparation
10) Sixth Field Work (9/99)	Discussion on DF/R, installation of the final simulation model, and holding a seminar

(6) Project Training

During the Study period, JICA invited four Iranian counterparts to Japan for the project training. Dr. Karbassi as the first trainee visited Japan in the spring of 1997 for 18 days. He studied Japanese experience on air pollution control in general from historical legal aspects, countermeasures, data collection, etc. His understandings were invaluable for the execution of the Study and will be so for the future utilization of the Study outcomes.

Mr. Azari's project training for three weeks in September 1997 was very helpful for the benefit of the propagation of the stack gas monitoring technologies to engineers and technicians at the sites, because he prepared the related manuals and know-how in Farsi and helped the transfer from the JICA member at the site.

Mr. Samadi stayed in Japan for three weeks in November 1998 to learn about data management and air pollutants' diffusion simulation. Mr. Amiri visited to learn Japanese ways of EIA preparation and authorization in May-June 1999. The crops of both training will be effectively used for the planning of new thermal power plants.

(7) Technology Transfer

In addition to the project training, the JICA Team made a possible effort to transfer related technologies, because it was one of the objectives of this Study. During the First Field Work stage, the first seminar was held to give general idea of the Study. Around 30 people attended the seminar from twelve different Iranian organizations.

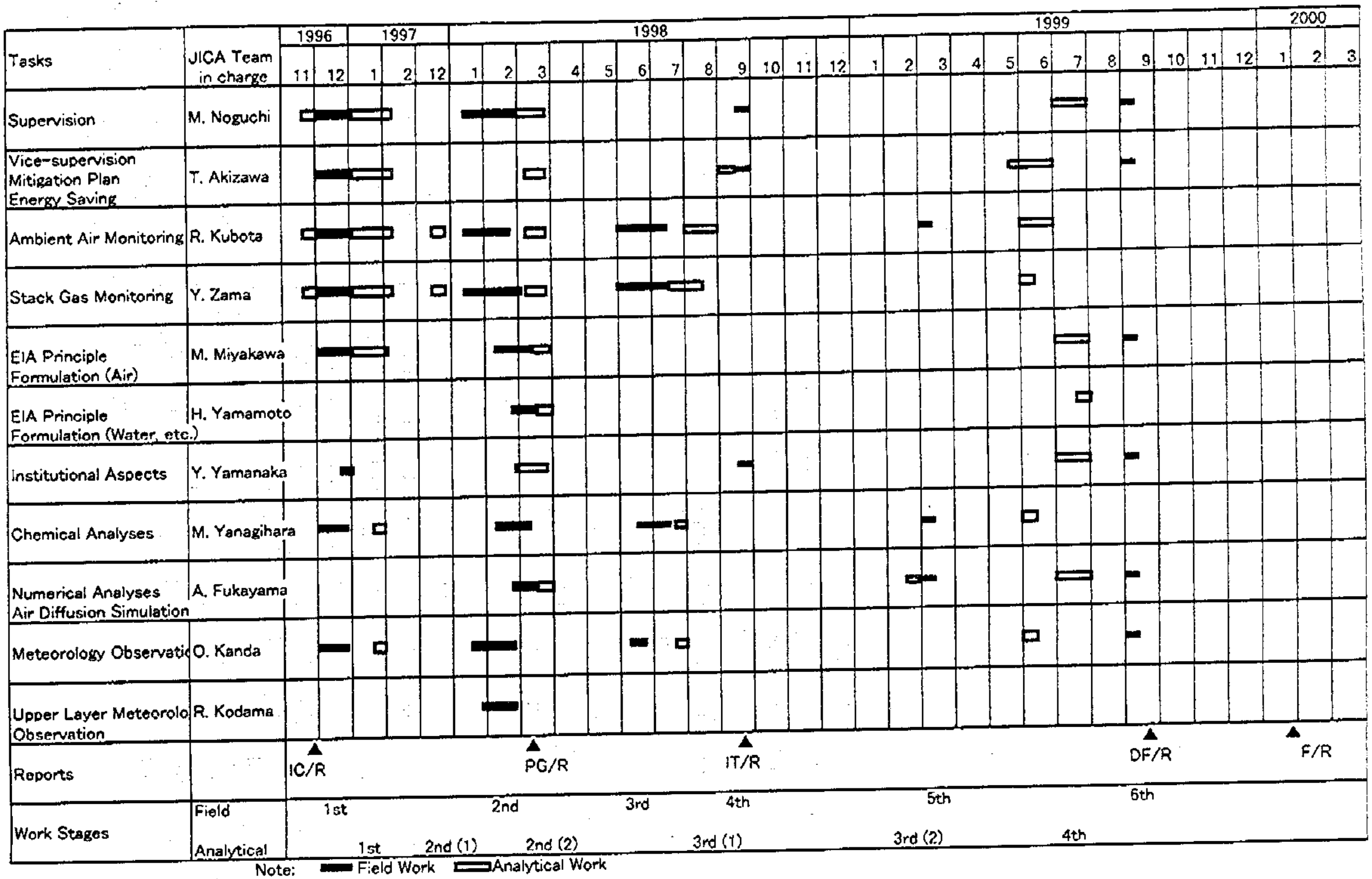
During the second and third Field Work periods, several small class rooms were held at both plant sites to introduce in details the technologies to be applied for the Study, to the counterparts and local cooperators by the JICA Team member. Also OJT (On-the-job-training) was carried out whenever any one of the JICA Equipment was mobilized to use at first at the site. An experienced member of the JICA Team showed his technologies of how to operate, inspect, and maintain the equipment, and subsequently guided the Iranian people to follow his technologies repeatedly until his confident of the transfer. Written materials prepared and distributed by the JICA Team member in those occasions are in the Appendix Section of this Report. Catalogues and manuals of equipment suppliers were also used for the transfer. Each one complete set of those was presented respectively to MOE and two power plants.

Transfer of upper layer observation technologies was insufficient in the Second Field Work at Tabriz, because of no permission of the winter observation from related official agencies. Therefore, two cooperators of Tabriz, Messrs. Baibordi and Najafzadeh, were mobilized to Esfahan to learn the related technologies in the Third Field Work before the observation at Tabriz. Also Dr. Karbassi kindly prepared in Farsi the procedures of the observation. The winter observation, once missed, was carried out by the Iranian side in January 1999.

Computer models of the dispersion simulation for Tabriz and Esfahan target areas were presented by the JICA Team to the Iranian Team with the User's manual. The related technologies were transferred to the Iranian Team during the fifth and sixth Field Work in addition to the project training in Japan. The models can be refined by the Iranian Team with additional information of existing or future emission sources in the areas.

During the sixth Field Work, the second seminar was held to propagate the methodologies and results of the Study to the public. Around 120 people attended it from 55 organizations including power plants other than Tabriz and Esfahan, central and provincial DOEs, Ministries of Oil, Health, and Mines & Metals, Universities, Departments in MOE, and so on. An English pamphlet of about 130 pages was handed over to each attendee for its understanding of the seminar.

Table 1.2.6 Overall Schedule



CHAPTER 2 SOCIO-ECONOMICS IN IRAN

2.1 General

This chapter deals with socio-economical features in Iran, in order to give general concepts of the country for the development of various proposals as parts of the Study outcomes.

A) Iran in brief:

a)Name: Islamic Republic of Iran

b)Land: Area - 1,648,416 square kilometers;
Mountains - Alborz Range on North side from west to east,
Kopeh Dagh Range on Northeast, and Zagros Range on South & west
Highest - 5671 meters at Mt. Damavand in the Alborz Range
(#55): Lowest - 26 meters below sea level on the Caspian Sea shore
(#51): Most of the land - above 460 meters height
1/6 of the land - above 1980 meters height
1/6 of the land - barren desert, almost no rain fall

c)Weather (#51): Complex climate, subtropical to sub-polar
Winter - normally rainy, Summer - 1 to 50℃
Four seasons, with fairly abrupt changes

d)Population : 55,837,182 (October 1991 census #51), 59,500,000 (1996 census #92)
57% live in urban areas (#51)

e)Major cities: Refer to Table 2.1.1 below.

Table 2.1.1 Major Cities with Population and Altitude

Cities	Population	Altitude (m)	Remarks
Tehran	6,475,000	1110	Capital
Mashhad	1,759,000	985	Northeast
Esfahan	1,127,000	1575	In the Study
Tabriz	1,088,000	1362	target areas
Shiraz	965,000	1491	Old capital
Ahwaz	724,000	20	North of Gulf
Qom	681,000	928	Holy city
Bakhtaran	624,000	1322	
Hamedan	641,162*	1644	Historical city
Khorram Abad	505,120*	1171	
Rasht	442,495*	-3	Caspian coast
Karaj	439,019*	1360	
Arak	437,695*	1755	Heavy industries

Sources: Population (#81, 1996) and * (#11, 1984), and Altitude (#11) f)Official Language: Farsi - 14.9% of the population do not use Farsi (#51).

g)Education: 5 years of elementary, 3 years of intermediate or guidance school, 4 years of secondary or high school, and higher education

h)Calendar: two calendars in use commonly, besides Gregorian calendar

Persian solar - the first day of Year 1377 = March 21 1998 in Gregorian calendar

Islam lunar - 354 or 355 days in one year, the year 1419 is 1998.

i)Business hours - 7:30 to 16:00, no business on Thursdays and Fridays

j)Time - Through out Iran, it is 31/2 hours ahead of GMT. Daylight Saving Time, one hour ahead of the Iranian Standard Time, from 21 March to 21 September.

B) Economic data

a)GNP: US$ 108.5 billion in 1997 (#100)

b)GNP rate of growth (% annual): 4.8 in 1996, 2.8 in 1997, 1.7 in 1998 to 2002 (#100)

c)GNP per capita: US$ 1780, in 1997 (#100)

d)ditto rate of growth (% annual): 3.5 in 1996, 1.7 in 1997, and -0.8 in 1998 to 2002 (#100)

e)Currency: Rial (RI) - Official conversion rate Rls. 3000 = US$ 1 from 1995 and variable after September 1998 (Rls. 8000 = US$1 in Sept. 99)

f)Inflation rate: 23.2% in 1997 (#97), and 21.9% in 5 months from March 1999 (#99, 9/9/99)

C) Fossil Fuels

a)Reserves of energy resources - See **Table 2.1.2** in comparison with the World data.

Table 2.1.2 Proved Recoverable Energy Reserves in Iran (#82)

Resources	Recoverable Reserves (1990)		
	World	Iran	% in Iran
Bituminous coal/anthracite, 10^6 tons	460,600	193	0.04
Sub-bituminous coal/lignite, 10^6 tons	516,319	--	--
Crude oil and NGL, 10^6 tons	136,754	12,700	9.29
Natural gas, 10^9 m^3	128,584	17,000*	13.22

* Current known gas reserve is 25,000 x 10^9 m^3 (#91).

b)Production in Iran:

Crude oil - 198 x 10^6 tons in 1993, of which 63.45% exported (#51)

Natural gas - 72 x 10^9 m^3 in 1993 (#51)

Coal - 1.5 x 10^6 tons in 1997 (#99, 12/10/98)

D) Recent Developmental Events

Historically, the Islamic Republic of Iran was founded in 1979. It was at war with Iraq for eight years from September 1980 to August, 1988. The First Five-Year Development Plan was launched in 1989 to reconstruct post-war damaged Iran. Iran had made significant progress in a number of economic domains until 1993 during the implementation of the First Plan. The Second Five-Year Socio-economic and Cultural Development Plan has consecutively been implemented from March 1995 to March 2000 (#21).

As of September 1999, the cabinet endorsed the Third Five Year Plan for ratification by the Parliament. The Plan will go into effect from March 2000 until 2005. Hard currency expenditures for the five-year plan is estimated to be US$ 112.5 billion. The Plan anticipates an economic growth rate of 6%. Oil revenues during the 5 year term are expected to be about US$ 56 billion, the rest of the national revenue to be earned on exports of non-oil products, professional services, foreign investments and possibly other international sources (#99, 9/7/99).

2.2 Second Five-Year Development Plan

2.2.1 Basic Strategies

There are sixteen major objectives (goals) composed of total 206 basic policies detailed in the Second Plan (#16). No. 10^{th} objective is for the environmental protection and optimal utilization of the natural resources. All the objectives and policies of the Plan can be summarized as below with some modification to the publication of the World Bank (#41).

A) Exchange and Trade Policies - The objective is to improve international competitiveness.
   a) Reunification of the exchange rate
   b) Establishment of customs tariffs at levels commensurate with external competitiveness and providing sufficient protection for domestic production
   c) Elimination of all tariff exemptions for all producers
   d) Facilitation of entry to reduce monopolies
   e) Participation in international and regional organizations

B) Financial and Monetary Policies - The objective is to direct savings to manufacturing and directly productive activities.

C) Fiscal Policy - The objectives are to increase efficiency in the use of public resources, current and capital, to facilitate the implementation of ongoing projects, and to reduce dependency on oil revenue by expansion of non-oil export. Policies on the expenditure side are as follows:
   a) Reducing involvement of government in provision of services, transferring these to the private sector
   b) Gradual elimination of subsidies, especially in the oil, water, electricity, and post and communications sectors with a better targeting of benefits to lower income groups
   c) Greater push for privatization

d) Reduction in the size of government through integration of ministries/institutions with duplicative functions

D) Population Policies - Measures to be taken to reduce the rate of population growth

E) Employment and Human Resources

a) Expanding support for small and medium scale industry

b) Encouragement of cottage industries, especially in the rural areas

It seems that the Plan intends to establish the order in principal economic activities, to make society efficient in its usage of resources for socio-economic and cultural development, to exercise a strict supervision over the execution of projects, and to reduce dependency on inductive growth resulted from oil revenues.

2.2.2 Quantitative Objectives

The Plan aims to have annual average GDP growth of 5.1% at market price in 5 years (#16). The World Bank (#41) predicted that it would be equivalent to 2.7 % of GDP growth per capita.

Miscellaneous industries are expected to increase their productions as in **Table 2.2.1**. As reported, actual productions were 4.5 million tons of steel in 1994 (#52), 160,000 units of vehicles in 1997 (#99, 9/21/98), 23 million tons of cement in 1998 (#99, 12/19/98), and 9.4 million tons of petrochemicals in 1997 (#99, 9/17/98).

Table 2.2.1 Planned Increment of Major Industrial Products (#51)

Products	Unit	Year 1993	Year 1998	Growth 98/93	Annual Growth %
Iron Ore	tons	4,500,000	10,500,000	2.33	18.5
Coal	tons	930,000	930,000	1.00	0.0
Raw Steel	tons	3,000,000	6,500,000	2.17	16.7
Trucks	units	7,000	20,000	2.86	23.4
Buses	units	2,500	4,400	1.76	12.0
Passenger cars	units	34,000	177,000	5.21	39.1
Cement	tons	16,000,000	26,500,000	1.66	10.6
Copper	tons	110,000	145,000	1.32	5.7
Petrochemicals	tons	4,600,000	10,800,000	2.35	18.6

In order to supply primary energy to support the GDP growth, the Plan gives the basic policies of better utilization and optimal allocation of the resources.

The 10-year plan for 1989-1999 published by the Ministry of Oil forecasted crude oil production rate to be annual average of 3.7 % (#51, p223), from 3.3 in 1989 to 4.75 million barrels/day in 1999. Actual production was 1428 million barrels in 1993 (#51, p228) (or 198 million tons assuming its density to be 0.872 ton/m^3) which was equivalent to 4.1 million barrels/day. Other reference #52 reported that the production in 1994 was 3.6 million barrels/day. Although there are up and down of the production, the target seems to be easily exceeded before 1999.

As for natural gas, one of the primary energy sources in Iran, the reference #51 shows its production to be around 45,500 and 71,905 million m^3 respectively in 1990 and 1994. The annual average growth rate is 12.1 % in the four year period. From the description in the reference, this situation will continue until 1999.

Oil was expected to produce the highest revenue in the Governmental general budget as given in **Table 2.2.2** which was reconstructed from the publication of the Iranian Plan and Budget Organization (#16). As stated in the basic policy of the Plan, dependency on the oil revenue is apparently lessened towards to end of the Plan period.

Table 2.2.2 Profile of Annual Revenues during Second Five-year Plan (#16)

Revenue	1995	1996	1997	1998	1999
Oil Export[1], %	59.4	55.7	51.6	47.9	43.4
Tax, %	21.7	23.5	25.5	27.6	29.5
Others[2], %	18.9	20.8	22.9	24.5	27.1
Total Revenue, in %	100.0	100.0	100.0	100.0	100.0

Note 1) equal to (total foreign exchange revenue from oil) minus (amount disbursed for imports of oil products)

2) included electricity, oil, gas, post, telecommunications, foreign exchange sales, etc.

Table 2.2.3 indicates planned Governmental revenues and expenditures for 5 years in Rials (#16). The expenditure of each year is balanced by allocating less 175 billion Rials than the revenue of the year. However, actual expenditures were reportedly 60,742 billion Rials in 1997 (#52) instead of 46,733 billion Rials, and estimated as 89,686 and 105,266 billion Rials respectively in 1998 and 1999 (#99, 12/27/98). These are 30 to 70% higher than the planned ones. Corresponding actual revenues are unknown.

Sales prices of oil products in Iran are subsidized to protect consumers. Therefore, saving consumption is not a prevailed idea among people. The Government has been trying to suppress the annual consumption growth rate below 3 % by raising sales prices of gasoline, kerosene, diesel and fuel oils to respectively Rls. 100, 20, 10 and 10 per liter by the Law concerning the

Second Five Year Plan (#21). As of December 1998, one liter of leaded gasoline cost Rls. 200 and further price hikes of gasoline and kerosene were debated in the Parliament (#99, 12/22/98).

Table 2.2.3 Profile of Governmental General Budget during the Second Plan (#16)

		1995	1996	1997	1998	1999
Revenue	10^9Rls.	36,216	41,121	46,558	52,763	60,650
Expenditures	10^9Rls.	36,394	41,296	46,733	52,938	60,825
Current	10^9Rls.	22,596	24,385	26,118	28,423	31,635
Development	10^9Rls.	13,798	16,911	20,615	24,515	29,190

2.3 International Economical Relations

(1) Foreign Trades

A profile of Iranian imports and exports was planned as given in **Table 2.3.1** (#16 originally in US$) which was another expression of the highest placing of oil revenues in **Table 2.2.2.** The oil portion occupied around 86% of all exports in 1991 and it was planned to gradually decrease towards 72% in 1999. Reportedly, crude oil export was estimated to be US$ 18 billion in 1996 (#91) and it decreased to US$ 15.5 billion in 1997 (#99, 9/26/98). Major importers of Iranian oil are Japan, Italy, France and the Netherlands. Non-oil export was US$ 5 billion in 1995(#53). Non-oil export goods were carpets, fresh or dried fruit, manufactured goods, and others (#41).

The balance of the trade was unfavorable to Iran until 1992. However, it turned around from 1993, and actually it was US$ 6 billion in favor to Iran in 1994 (#52) and US$ 7.5 billion in 1996 (#97).

Table 2.3.1 Imports and Exports in Iran (#16)

Items	1991	1992	1993	1994	1999	Annual Growth 94/99
Imports	27,450.0	23,500.0	15,820.3	16,508.1	20,419.3	4.3 %
Exports	18,412.0	19,283.0	16,820.4	17,580.3	22,061.3	4.6 %
Oil	15,802.0	16,343.0	13,019.6	13,460.4	15,896.0	3.4 %
Non-oil	2,610.0	2,940.0	3,800.8	4,119.9	6,165.3	8.4 %

unit : million US $, except %

(2) Direct International Connection

After hosted Islamic States General Assembly participated by high ranking delegation of 55 countries in December 1997, Iran has greatly enhanced its relation with those countries and increased air connections with major cities in those countries. This will surely improve economical, technical, and cultural relationship within the region.

(3) Tourism

Iran has vast amount of archaeological, historical and cultural monuments to offer international visitors. A general manager of Iran Air Far East Region disclosed in its pamphlet that number of Japanese to Iran increased 39, 86 and 66 % respectively annually in 1995, 1996 and 1997. The number is expected to be in the range of 15,000 to 20,000 in 1998.

Visitors from Europe and others are also becoming flourished allegedly. Total of roughly 350,000 tourists traveled to Iran in 1994 (#52). The income from the tourism will somewhat compensate for dependency on the oil export revenue.

CHAPTER 3 ELECTRIC POWER IN IRAN

3.1 General

3.1.1 Electric Sector

The Sector was initially brought to Iran in 1903 with two small steam turbines of 100 and 400 KW and 50 employees (#24). In 1969, Iran Power Generation and Transmission Company (TAVANIR) was founded. There were several reshuffling of the whole organization, such as the one in 1986 when each regional electricity company was assigned to take the overall responsibility of electrical energy supply including generation, transmission, dispatching and distribution (#84). Finally the current organization for electric power sector under the Deputy of Power Affairs, MOE is as in **Fig. 3.1.1**. Its center office is responsible for supervision and control of power sector enterprises, acting as policy making body.

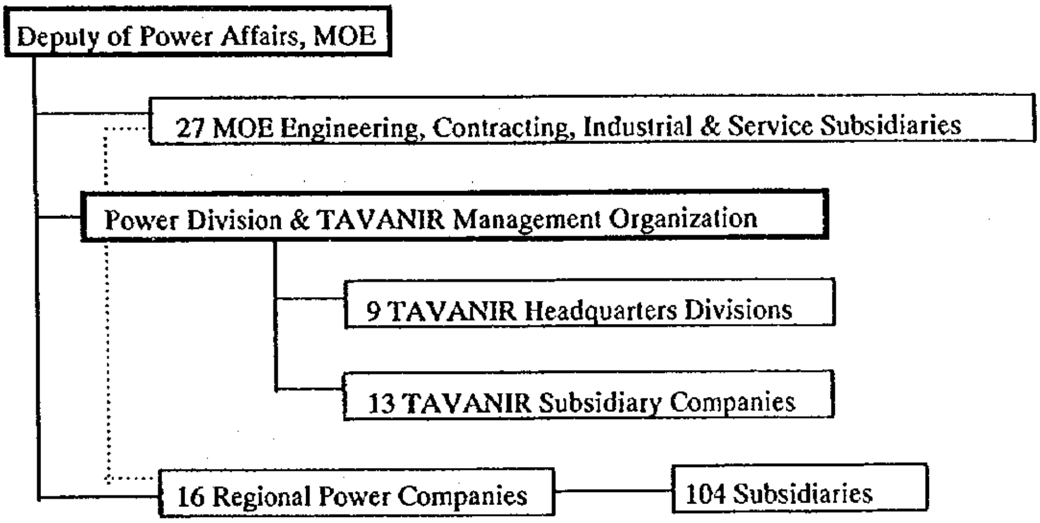


Fig. 3.1.1 Organization Chart of Power Industry under MOE (#98)

The 104 subsidiaries under the Regional Power Companies are for generation, distribution, dam operation, and others (#98).

As the results of effective measures for, such as, upgrading man-power skill, R & D, and improving efficiency of generation, transmission and distribution facilities, the power industry has succeeded in 1993, for the first time after victory of the Revolution and after a period of 20 years, in bringing the blackouts to the level of zero. Once the long and arduous years of power shortage were left behind and extensive power cuts were over (#24).

During the First (1989 - 1994) and the Second (1995 - 2000) 5 year Development Plans, privatization has been continued in management of generating and distribution companies (#24). The following are some of the basic objectives and guidelines of the Second 5 year Plan with regard to the Sector (#25):

- Continuation of attempts for suitable organization and compilation of an optimum structure for the Sector.
- Improvement of consumption management, savings and rational use of electricity.
- Research development and increasing the use of local productions for the erection of industrial electricity installations.
- Raising standards of soft-wares and project management in order to maximize the use of hard-wares existing in development and reconstruction.
- Improved operation and optimum use of industrial electricity installations.
- Attempting to develop and raise information technology in the Sector.

3.1.2 Electric Power Demand & Supply

There are government-run power plants affiliated with the Ministry of Energy (MOE) and some private-run power plants affiliated with large industries and others in Iran. **Table 3.1.1** shows the consumed amounts of MOE produced electricity by demand sectors in Iran. The maximum power consumption sector is the residential, followed by the industrial and commercial sectors.

Table 3.1.1 Electricity Consumption by Sectors in Iran (MOE) (#23~25, #98)

Year	Residential	Commercial	Industry	Others	Total (GWh)
1990	17,344	11,930	10,220	5,613	45,107
1991	19,128	13,609	10,637	5,801	49,175
1992	19,509	14,004	13,262	5,531	52,306
1993	22,143	14,984	15,572	5,415	58,114
1994	22,460	13,743	20,487	6,935	63,625
1997	26,523	14,887	23,661	8,287	73,358

Table 3.1.2 shows the installed capacity of electric generation itemized in accordance with the types of generation affiliated with the MOE. Steam power plants have a share of 50.2% of the total capacity (23,257MW in 1997), followed by gas turbines 38.3%, and hydroelectric power plants 8.6%. Reportedly 800 MW was completed in 1998 and additional 1400 MW will be in operation in 1999 (#104).

Table 3.1.2 Installed Capacity of Electric Generation (MOE)

Year	Hydraulic	Steam	Gas Turbine	Diesel	Total in MW
1990	1,953	8,086	3,940	824	14,803
1991	1,953	8,086	3,940	869	14,848
1992	1,953	8,710	4,794	856	16,313
1993	1,953	9,513	5,934	812	18,212
1994	1,953	10,742	7,007	758	20,460
1997	1,999	11,685	8,896	677	23,257

Source : #23~#25, #98 Note : Gas turbine data includes combined cycle power plants

Table 3.1.3 tabulates generation data in Iran. A total of 92,309GWh of electricity was generated by the MOE in 1997. The steam power plants generate about 71.1% of all electricity, 20.9% by gas turbine, and 5.1% by hydraulic source. Again the steam-power accounts majority. The annual load factor was 57.2% in 1997 (#98).

Annual average growth rate of generation was 7.4% during 1989 to 1997. Annually one 1600 MW plant has to be constructed to satisfy the 7.5% of growth. It is reported that an annual investment of US$600 million is required to construct it together with transmission and distribution facilities (#105).

Table 3.1.3 Electricity Generation (MOE)

Year	Hydraulic	Steam	Gas Turbine	Diesel	Total in GWh
1991	6,803	38,836	8,723	1,254	54,896
1992	7,056	41,947	9,463	1,244	59,710
1993	9,330	42,362	10,866	1,224	63,782
1994	9,823	48,166	12,419	927	71,335
1995	7,445	53,376	15,402	863	77,086
1996	7,376	62,364	15,475	610	85,825
1997	6,908	65,628	19,298	475	92,309

Source : #23~#25, #98 Note : Gas turbine data includes combined cycle power plants.

Appendix 3-1 is a list of power plants with their nominal generating capacities, including under construction and planned to be constructed, known to the JICA Team. All the operating power plants having larger than 1000 MW capacity are based on steam power, although larger hydraulic power generation plants are under planning or construction. The largest single power generation units in one plant are in the range of 200 to 450 MW.

3.2 Thermal Power Plants in the Study

3.2.1 Specifications

Table 3.2.1 gives the general specifications of existing units at the Tabriz and Esfahan power plants. The boilers of the Tabriz plant are forced-circulation, tangential firing type. These are designed to combust Az residual fuel oil and natural gas simultaneously. The Tabriz plant is burning the fuel oil only. The Esfahan plant is burning Bz residual fuel oil and natural gas together in summer and the fuel oil only in winter. Its piping system has enough capacity although not enough gas itself in winter. No stack gas emission control unit is installed in the plants. No expansion plan is at Tabriz nor at Esfahan.

3.2.2 Operation of Power Plants

(1) General

The electricity demand in Iran is low from midnight and to early morning, higher in daytime, and highest at night from 18:00 to 22:00. Major operations are instructed to each power plant by the central dispatcher three times during 7 - 9, 16:00 - 18:00, and 22:00 - 24:00.

1) Tabriz Power Plant

Tabriz power plant is normally in operation with 200 - 350MW depending on demand, burning fuel oil at present. However, No. 2 Unit was out of operation for a long period (March to November 1998) during the Study because of heavy maintenance.

15% re-circulation of total stack gas is employed in order to control steam temperature and generation of nitrogen oxides from the boilers. The facilities look well-worn because of war damage and local repairs, although these were in operation from 1986 and 1988.

Underground water from 14 deep-wells in the surrounding area of the plant is used for cooling or boiler feed after demineralization. Cooling water is re-circulated after passing through a steam condenser and a cooling tower. In winter when the ambient temperature is low, visibility is decreased by steam condensate from the cooling tower and the sky is clouded over the surroundings.

2) Esfahan Power Plant

Esfahan power plant is normally in operation with capacities: 50% of Unit 1 and 2, 60% of Unit 3, and 50 - 100% of Unit 4 and 5. Unit 1 and 2 have natural-circulation and front firing boilers. Unit 3 boiler is the natural-circulation and tangential firing type. Forced-circulation and tangential firing are used for Unit 4 and 5 boilers.

Table 3.2.1 Specifications of Existing Units at Tabriz and Esfahan Power Plants

Power Plant	Unit	Rated Output (MW)	Fuel Type*2)	Fuel Burnt (t/h)*3)	Assumed Stack Gas (m^3N/h)*4)	Stack Gas Temp. (℃)	Stack Gas Velocity (m/s)	Stack Height (m)	Stack Diameter (m)	Environmental Measures for Existing Facilities	Cooling Tower	Manufactures	Start Up Year
Tabriz	1	368	Az Fuel Oil	65.0	950,000	160	13.5	120	5.0	15% re-circulation of total stack gas	Forced Cooling	Alsthom-Hitachi	1986
	2	368		65.0	950,000	160	13.5	Central-ized	5.0			Alsthom-Hitachi	1988
Total	2*1)	736											
Esfahan	1	37.5	Gas Oil & Natural Gas	6.0	87,000	180~190	13.6	25	1.5	None	Forced Cooling	Francotossi	1969
	2	37.5		6.0	87,000	180~190	13.6	25	1.5			Francotossi	1969
	3	120	Bz Fuel Oil & Natural Gas	30.0	440,000	180~190	24.9	55	2.5			Stein	1974
	4	320		71.0	1,030,000	170	14.6	80	5.0			Francotossi	1980
	5	320		71.0	1,030,000	170	14.6	80	5.0			Francotossi	1988
Total	5	835											

Note : *1) - There are 2 units of Gas Turbine (32MW×2, Fiat company, start up in 1978) at Tabriz power plant in addition to the 2 boiler units.
*2) - Az, Bz: Types of residual fuel oil in Iran, classified mainly with difference of viscosity.
*3) - In the case of oil only used. The amounts are as reported by each power plant.
*4) - Assumed by the JICA Team based on the fuel oil burnt. The JICA Preparatory Team reported that it was 1,419,400m^3/hr at 440 MW Neka Power Neka burnt fuel oil at the rate of 112.5 tons/hr for generation of 440 MW.

At present, mixed combustion of gas oil and natural gas is used for Unit 1 and 2, and Bz only or mixed combustion of Bz and natural gas is for Unit 3, 4, and 5. As the allocation of natural gas is decreased for electricity generation in winter because of its priority use for heating for the houses, Units 3, 4, and 5 have been fueled with Bz only.

Underground water from 4 wells in the surrounding area of the power plant is used for boiler feed or cooling. Cooling water is circulated through a condenser and a cooling tower. In winter when temperature is low, the steam condensate from the cooling tower does not have so much influence as that of Tabriz though white smoke from the towers is visible.

(2) Combustion Control

In order to burn fuel completely by burners, the amount of excess air has to be carefully controlled. The ratio of the amount of air to the theoretically required air for burning fuel is generally 1.2 - 1.4, in the case of natural gas or fuel oil as fuel. The residual oxygen concentration in stack gas is normally about 4~6%.

With excess O_2 in the stack gas, boiler thermal efficiency decreases and the thermal loss increases, although fuel utilization efficiency improves.

O_2 concentrations in stack gas were high during the measurement of the Study. The residual O_2 concentration was 12.2 - 13.5% of Unit 1 at Tabriz, and in the range of 8.8 - 16.9% at Esfahan. The following are probable reasons for high O_2 concentrations:

-- Excess combustion air

-- Excess air leakage from air heaters.

-- a combined effect of the above two influences

Generally, a flue gas rate per MW is higher at a lower MW capacity. Actual flue gas flow rates per MW close to the design capacity were 25 to 40% more than the design at Tabriz and 20 to 30% more at Esfahan. These excess flow gas evidences excess air ratio in operation and air leakage into the boiler systems. Combustion control and maintenance of related equipment must be stressed more than enough repeatedly.

(3) Logged Operational Data

Appendix 3-2 is obtained for one month logged operational data at 14:00 o'clock at both of Tabriz and Esfahan. The summary of the data is given in **Table 3.2.2.**

a) Stack gas temperature is 40 to 65 deg C higher than the designed one at Tabriz. At Esfahan, the differences are negligible. The temperature measured in the Study indicated it was in 38 deg C higher at Tabriz (Aug. 8, 1998) and 21 deg C at Esfahan (June 6, 1998). By this wide fluctuation of stack gas temperature, both plants seem having unstable operation in some parts of the systems such as combustion control, heat exchangers, thermometers.

b) Steam temperatures incoming to turbines are well within the range of the designed ones.

c) Oxygen contents in flue gas measured at the outlet of the economizer are recorded in the log sheets as indicated in the control panel in Tabriz. However, it is almost impossible to operate the boiler of fuel oil combustion with oxygen below 1 % in flue gas. The oxygen meter was found not calibrated.

d) Differences of cooling water inlet and outlet temperatures at the steam condensers were higher than the designed one at Tabriz and lower at Esfahan. Tabriz, in operation close to its design power generation capacity (368MW), was in trouble of a water supply system. It seems this water supply is the limiting factor of power generation at Tabriz No. 1 unit. Although there was no water flow meter at Esfahan, the power plant seems in good conditions of its condenser system from the standpoint of water temperatures, because of help of higher condensing temperature of steam. There always remains uncertainty of temperature indications at both plants.

e) Both plants were in operation of the absolute pressure at each condenser to be about 20 mmHg higher than the designed values. The JICA Team could not identify reasons of the difference, any capacity failure of a booster ejector or a vacuum blower. Higher operational pressure at the condenser means less efficiency at the turbine, because of inhibition of steam expansion in the turbine.

(4) Load Factor

The Annual load factor of the Tabriz power plant was 61.4% in 1993 (#09) and 86% (#Report of the JICA's Preparatory Study, 1996). The factor at Esfahan was 62.3% of Unit 3, 60.2% of Unit 4, 74.1% of Unit 5 and 66.1% of Unit 3 to 5 as a whole (#30), or 71.6% (65 - 81%) (#JICA Preparatory). The factors are comparatively higher than those of common knowledge and indicate a need to start construction of additional power plants. The factor is higher in summer: high electricity demands for air conditioning.

Table 3.2.2 Logged Operational Data (Summary)

Plant	Item	Design	Log Data	Average	Remarks
Tabriz No.1 368MW	Stack gas temperature ℃	160	200~225	209	Capacity in the period: 320~350MW, Average 347MW
	Turbine Inlet Steam ℃	538	535~539	538	
	Turbine Reheated Steam In ℃	538	530~540	536	
	Economizer Flue Gas O_2 %	1	0.005~0.9	0.3	
	Condenser Water Inlet℃	21.6	21~33	28.4	Designed Temperature Difference: 8 deg C
	Condenser Water Outlet℃	29.6	41~46	43.5	Operational Temperature Difference: 15.1 deg C
	Condenser Pressure, mmHg	38.0	50~69	56.5	
Esfahan No. 4 320MW	Stack Gas Temperature℃	170	155~188 147~175	174 161	Capacity in the period: 210~320MW, Average 270MW
	Turbine Steam Inlet ℃	538	540	540	
	Turbine Reheated Steam In ℃	538	540	540	
	Economizer Flue Gas O_2 %	0.5	--	--	
	Condenser Water Inlet ℃	33	30~33.5	31.5	Designed Temperature Difference: 11.8 deg C
	Condenser Water Outlet℃	44.8	36~46	41.1	Operational Temperature Difference: 9.6 deg C
	Condenser Vacuum, -mmHg	580	540~575	559.2	

Note) All logged data at 14:00 o'clock from August 17 to Septemer 18, 1998 at Tabriz, and from July 23 to August 21, 1998 at Esfahan.

(5) Power Generation Efficiency and Internal Consumption

Power generation efficiency was 33.7% and 33.6% individually at No. 1 and 2 of Tabriz Plant in 1996 (#89). It is quite low in consideration of the plant size. On the contrary, internal consumption of power was 7.5% and 7.7% at No. 1 and 2 plants of Tabriz in 1996 (#89), and 8.0 to 8.63% at Esfahan in 1993 and 1994 (#30). The numbers are high in comparison with recent power plants of the similar size.

3.2.3 Emission Control Measures at the Power Plants

1) Tabriz Power Plant

The installation of electrostatic precipitators was tried in the past at the Tabriz power plant when it received complaints concerning air pollution from farmers living in the surrounding area. No facility implementing environmental measures has been installed since the complaints were received.

Smoke from the stack has brown to gray color from soot and steam condensate. The 120m concrete, centralized for 2 units, stack is employed in order to improve diffusion and to mitigate air pollution in the surrounding area. The 15% re-circulation of total stack gas is employed in order to control steam temperature and generation of nitrogen oxides from the boilers.

Wastewater from the power plant is discharged into the river without treatment.

2) Esfahan Power Plant

No facility implementing pollution control measures is employed at the Esfahan power plant. The power plant is close to a residential area. The township of Qa-e-Mich is located to the north of the plant beyond a hill of 300 m height. The exhaust gases from the low stacks of the plant is likely to go down the hill to the area. People there has complained air pollution affected by smoke.

The plant is trying to burn natural gas to alleviate the pollution. However, availability of the gas prohibits its use in winter at all units. Therefore, the plant is using the gas in winter at No. 1 and 2 units having lowest stacks.

Wastewater from the power plant is discharged into the river flowing along the plant site after neutralizing, precipitating and filtrating.

3.2.4 Fuel at Power Plants

(1) Properties of Fuel

Table 3.2.3, and 3.2.4 list properties of the residual fuel oil at the two plants.

Table 3.2.3 Properties of Residual Fuel Oil

	Used at Tabriz	Used at Esfahan	NIOC Specification	
Fuel Oil Type	Az	Bz	Az	Bz
Heating Value Btu/lb		18280	Min. 18,200	Min. 17,500
Viscosity @100℃ cSt	47.9 ~ 63.7	70.1	-	Max. 72
ditto @50℃ cSt, Winter	-	-	150	-
ditto @50℃ cSt, Summer	-	-	200	-
Flash Point °F	221	220	145	Min. 150
Specific Gravity 60/60 °F	0.96 ~ 0.98	0.9715		0.9980
Total Sulfur (%)	1.8 ~ 2.1	3.13	Max. 3	Max. 3.5
Pour Point °F	37.4 ~ 41	more than 55	-	Max. 100
Pour Point °F, Winter	-	-	40	-
Pour Point °F, Summer	-	-	60	-
V ppm wt.	34 ~ 80	86	Ash Max. 0.05 Wt.%	About 150
Ni ppm wt.	15.4 ~ 17.6	25		About 40
Na ppm wt.	47 ~ 52	12		About 15
Water & Sediment Vol.%	0	-	Max. 0.5	-
Data Source	#56	JICA Preparatory Team Report		

Table 3.2.4 Properties of Natural Gas at Esfahan Power Plant

Components	Volume %
C_1 %	89.72
C_2 %	3.57
C_3 %	1.09
i-C_4 %	0.22
n-C_4 %	0.30
i-C_5 %	0.13
n-C_5 %	0.09
C_6 %	0.08
C_7 %	0.05
C_8 %	0.03
C_9 %	0.02
N_2 %	4.7
CO_2 & H_2S	not given
Kcal/m^3	8,680

(# JICA Preparatory Team Report)

(2) Fuel Transportation and Storage

Fuel burnt at Tabriz is piped from the Tabriz Refinery of the National Iranian Oil Company, 8 km apart from the power plant. The World Bank report (#17) recommended the conversion of oil to natural gas by March 1996. However, construction of the piping to transfer natural gas has been suspended for the time being.

Fuel oil is transported by lorries to Esfahan Power Plant from the nearby refinery by road at the rate of around 200 lorries per a day. Natural gas is conveniently piped from the refinery.

3.3 Energy Saving at Power Plant

3.3.1 Energy Loss

Fig. 3.3.1 shows an example of heat balance at the thermal power plant. Only 40 % of heat input by fuel combustion is converted to electricity.

Besides, electricity is consumed internally in the power plant for power and lighting, which represents a substantial percentage of the generated amount; usually 3 - 6%.

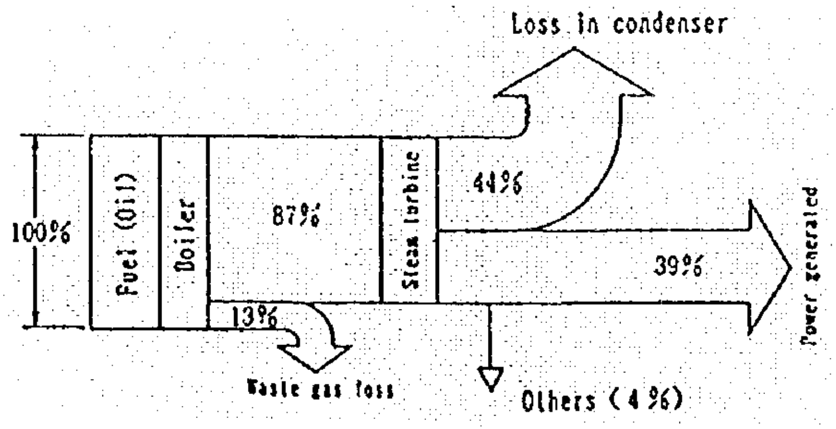


Fig. 3.3.1 Heat Balance of Thermal Power Generation (Oil fired: 600MW) (#83)

3.3.2 Energy Saving Plan in Power Plant

Three measures are generally employed for energy saving of existing power plants.

a) Application of strict management on operation and maintenance of equipment: No large investment required

b) Remodeling of or addition to existing equipment: Considerably large investment required

c) Replacement with new unit or equipment: Highest investment required

As in **Fig. 3.3.1**, energy loss is 44% in the condenser and 13% in the boiler with stack gas , of the total heat input to the generation system. Therefore, it is understandable to apply energy saving measures to those major losses.

For new construction or scrap-and-build of power plants, there are also options to select. Common measures of energy saving in the power plants are briefly described in **Appendix 3-3.**

3.3.3 Concerns over Energy Saving of Both Power Plants

(1) General

Energy saving at power plants by increasing thermal efficiency, lowering heat loss with stack gas, or else is not only for preservation of not-renewable fossil fuels but also for reduction of CO_2 emissions which is a concern of global warming.

Because of abundant energy deposits and governmental subsidy of energy prices, it seems energy in Iran is just like a substance limitless in the earth. Gasoline price is far less than prices in the world, and electricity price (Rls. 60/kwh) is allegedly less than half of the production cost

(Rls. 138/kwh) (#105). Under these situations, it is unavoidable and regrettable that operators and managers of both plants seem not to concern about keeping or improving thermal efficiency of power generation.

(2) Control of Stack Gas Temperature

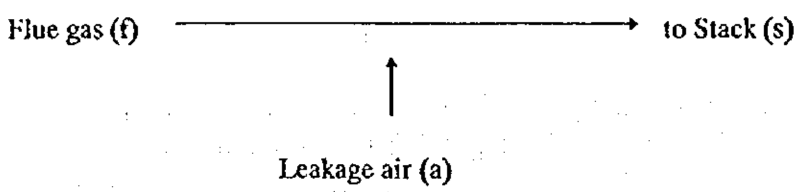
As in **Table 3.2.2**, stack gas temperatures of both plants are higher than designed values with more than 20 deg C. Major loss of energy in the boiler is with stack gas. To control the stack gas temperature requires to control combustion and to maintain well air heaters. These are to reduce an amount of stack gas flow and to increase heat transferred to combustion air from stack gas.

(3) Management of Oxygen in Stack Gas

This is related to the above consideration. Combustion control is the must in order to increase thermal efficiency of power plants by controlling air flow rates and utilizing heat in stack gas. The most important item for the purpose is to control oxygen contents in the stack gas. If it is possible to reduce combustion air flow, it will reduce power consumption of air blowers and heat loss with stack gas. Both plants were in operation with broken (supposed to be continuous) indication of the oxygen contents on the control panels. The oxygen contents were periodically checked by Orsat meters. The panel (or on-line) oxygen meters should be repaired or calibrated correctly and the plants should be operated with appropriate combustion control in mind.

(4) Reduction of Air Leakage from Air Heater

Most of oxygen contents measured in the Study were more than 10% in the stack gases. This means boiler system is in operation with extremely excess air. By assuming several values, excess air rate can be calculated for the data of June 20 1998 at Tabriz as follows:



Oxygen contents	$O_f = 0.025$ (assumed), $O_a = 0.21$, $O_s = 0.135$
Gas flow rates	G_f = unknown, G_a = unknown, $G_s = 1{,}040{,}000\ m^3N/h$
Oxygen balance	$G_f \times O_f + G_a \times O_a = G_s \times O_s$
Gas balance	$G_f + G_a = G_s$

The two unknown quantities (Gf and Ga) can be obtained from two simultaneous linear equations.

$$Ga = Gs \times (Os - Of) / (Oa - Of)$$

$$Ga = 1{,}040{,}000 \times 0.11 / 0.185 \fallingdotseq 618{,}000 \; m^3N/h$$

The air leakage (Ga) is tremendous amount. The temperature of the stack gas was 195℃. By assuming the air temperature to be 25℃, specific heat of air 0.25 kcal/(kg x deg C), and molecular weight of air 29, it is 34,000,000 kcal/h of heat loss accompanied with the stack gas to atmosphere. This heat is equal to 3.4 tons of fuel oil or 5.2% of fuel oil burnt at that time of measurement. The above calculation involved several uncertainties such as accuracy of measurements and error of assumptions, all of which can be overcome with repeated and additional measurements.

Air leakage can be reduced with maintenance of the air heater and reducing a stack draft by lowering gas temperature. Actually, Tabriz Power Plant reported the oxygen contents was 3 to 6 % after maintenance of its air heater. Detail of the measurement and maintenance is unknown to the JICA Team.

(5) Control of Vacuum at Condenser

As given in **Table 3.2.2**, condensers at both plants were operated at 20 mmHg higher than the designed values. It decreases the work to be done by steam expansion and reduce the turbine efficiency.

Both plants should keep the condenser vacuum at the designed degree by keeping cooling water as much as possible at the designed temperature and flow rate, and also by maintaining equipment regularly; such as a) measurement instrument check and calibulation, b) checking of air leakage at vacuum system, c) cleaning of condenser tubes, and d) check of vacuum generating system. Generally the vacuum should be within ±3 mmHg of the designed value.

(6) Reduction of Internal Consumption

As pointed out before, internal consumption of electricity at both plants is quite large. They should try to reduce it by daily check and maintenance and with minds of energy saving.

3.4 Air Pollution Control Measures

3.4.1 General

No electrostatic precipitator, nor other pollution control device is installed at Tabriz or Esfahan, except stack gas re-circulation at Tabriz without knowing its effectiveness in NOx reduction. It is easily supposed that a high concentration of particulates is emitted from the stacks by judging from its visible light black color of stack gas. SOx and soot emissions are high at both power plants when burning fuel oil.

However, one year monitoring of air qualities surrounding the plants indicated SO_2 and NO_2 concentrations were less than the concentration of Iranian National Standards. SPM was also below the annual average value of the National Standards. Only daily average SPM in ambient air seems to exceed the Standards at Esfahan. SPM are generated not only at power plants, but also other plants and natural sources. The air pollution caused by both power plants seem not so high within the limit of the Study. In addition, there is no expansion plan at Tabriz and Esfahan and both power plants are switching their fuel from fuel oil to natural gas although the dates of the complete switch are not yet decided. Future pollutant emissions from the plants will be less than the current ones.

According to stack gas monitoring data, emissions of SO_2, NOx, and SPM exceeded the proposed emission standards by DOE. However, by switching the fuel from fuel oil to natural gas, all three will be below the proposed standards.

As commented before, both plants are operated beyond the design value and loosing energy. To improve thermal efficiency is to reduce fuel consumption and finally to reduce pollutant emissions including CO_2.

3.4.2 Air Pollution Control Measures at Power Plants in General

One of the objectives of this Study is to contribute MOE to increase its own capability for implementation of mitigation plans on other existing and planned thermal power plants. Therefore, the JICA Team presents here air pollution control measures for a thermal power plant in general, even if there is no need to plan for the two plants: Tabriz and Esfahan.

Air pollutants originating from thermal power plants include sulfur oxides (SOx), nitrogen oxides (NOx), and soot. Generally, air pollution control measures taken at thermal power plants can roughly be classified into three categories; i.e. fuel, facility and operation measures. These three measures are integrated to work together in the best way.

The outline of air pollution control measures is as shown in **Figure. 3.4.1.**

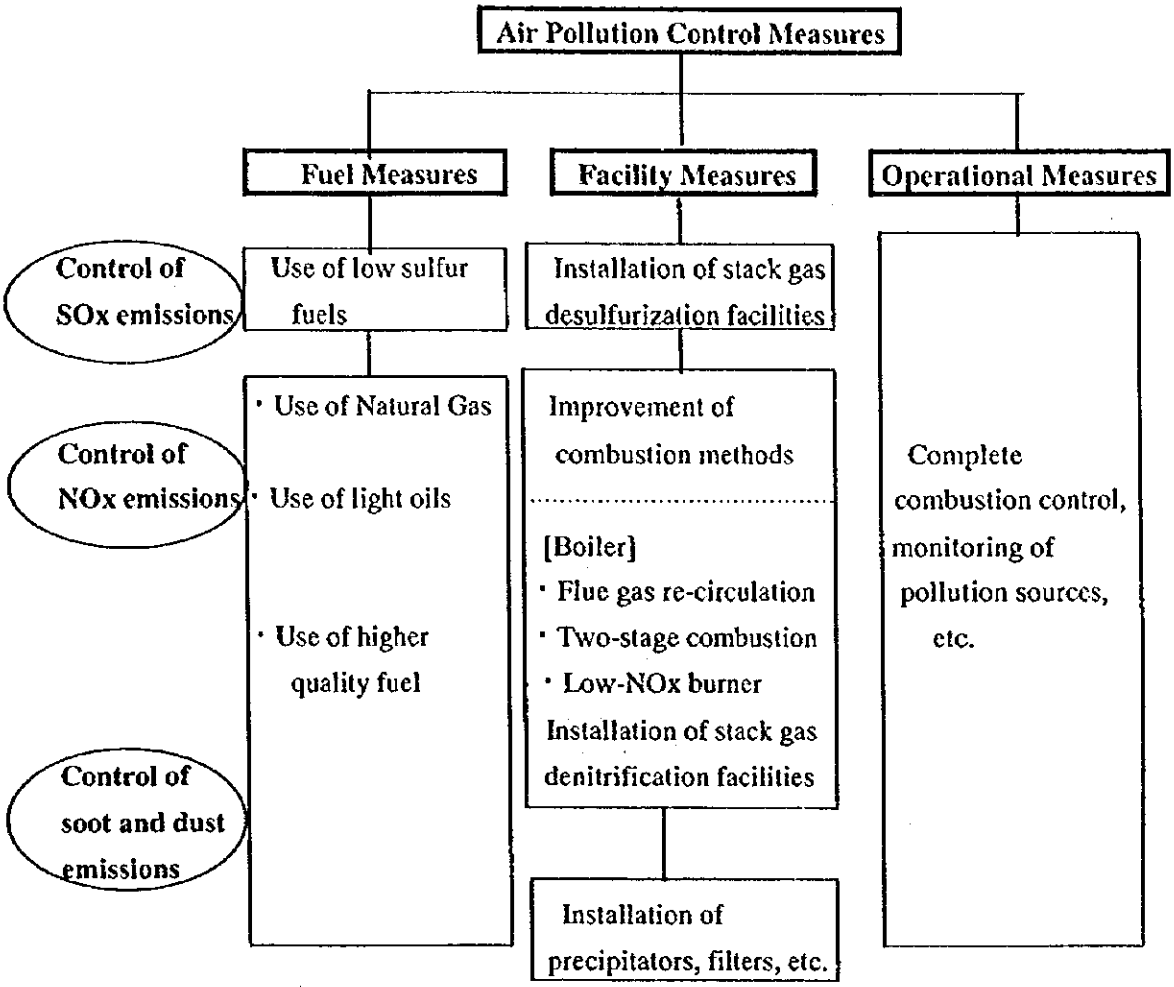


Figure 3.4.1 Outline of Air Pollution Control Measures at Thermal Power Plants

These measures should be selected from available resources (fund, material, human, etc.), national policy and economic conditions, available technology, location of the power plant, expected effects, etc.

In addition to the three categories, there is a method to diffuse pollutants by having a higher stack and higher velocity of stack gas from the top of the stack, and also having a centralized stack. This method is effective to alleviate pollution close to the power plant. However, pollutants will eventually descend somewhere on the globe.

Planning of control measures and their implementation has to be carried out after consideration of emission allowances, effects on the environment, availability of space, expected life of the measures, difficulty of retrofitting, construction schedule, etc.

For reference, individual measures for control soot, NOx and SO_2 emissions are summarized in **Appendix 3-4**.

3.5 Waste Water Treatment in Power Plants

Both power plants seem not to well prepared to meet the National Waste Water Disposal Standards (#90) published by DOE. There are five kinds of waste water streams from thermal power plants: a) Oily water, b) Chemical waste water, c) High SS (suspended solid) water, d) Blow down water, and e) Toilet and kitchen waste.

Although there are neutralization and coagulation facilities in Esfahan, high SS will escape through the facilities and flow into a river. And there are not enough facility to treat oily waste water such as floor drains. Tabriz does not have any waste water treatment facility.

A schematic flow sheet is given in **Appendix 3-5** as an example of a typical waste water treatment unit in a thermal power plant from quality protection of river water.

CHAPTER 4
LAWS AND INSTITUTIONS FOR ENVIRONMENT PROTECTION

4.1 Environmental Control in National Government

4.1.1 Decision Makers

The constitution of the Islamic Republic of Iran has expressed a strong commitment towards protecting the environment. Its Article 50 states that *'Protection of the environment, in which the present and future generations must lead an ever-improving community life, is a general obligation. Therefore, all activities, economic or otherwise, which may cause irreversible damage to the environment, are forbidden'* (#17).

The highest authority in the Islamic Republic is the Leader. Next to the Leader, the second highest authority in Iran is the President who nominates twenty two ministers controlling respective sectoral ministries(#51) as in **Table 4.1.1** and also nominates vice-presidents. Under the provision of the Constitution, all legislation must first be approved by the Parliament (Majlis) and then be ratified by the Guardian Council of the Constitution (in effect an Upper House). Finally the legislation is signed into the law by the President.

Table 4.1.1 Ministries in Iran

Agriculture and Rural Development	Health and Medical Education
Commerce	Housing and Urban Development
Construction Crusade	Industry
Cooperatives	Intelligence
Culture and Higher Education	Interior
Culture and Islamic Guidance	Justice
Defense	Labour and Social Affairs
Economic Affairs and Finance	Mines and Metals
Education	Oil
Energy	Post, Telegraphs and Telephone
Foreign Affairs	Road and Transport

The President heads the Environmental High Council (EHC) which is composed of two vice-presidents, all (ten) economic cabinet ministers , the attorney general, and experts as members. Within the ten ministries, four (Agriculture, Energy, Industry, and Mines and Metals) have their own environmental section. Naturally, other Ministries are dealing with pollution in each capacity; for example, Ministry of Health and Medical Education with public health, Ministry of Education with environmental education of school children, Ministry of Oil with various pollution caused by drilling, processing, usage, etc.

EHC is quite broad and strong in deciding on environmental policies, strategies, and standards. It is assisted by four coordinating councils on different aspects of environment, such as 1) environmental programs, 2) environmental research and information, 3) environmental education and awareness, and 4) environmental and sustainable development (#17).

4.1.2 Department of Environment

Department of Environment (DOE) is one of organizations included in the President's Office. DOE was originally founded in 1971 with general jurisdiction for environmental protection and broad powers based on the Game and Fish Law of 1967 (#55). It is now responsible for controlling any activity considered damaging to the environment assigned by the Environmental Protection and Enhancement Act of 1975 enacted after the United Nations' Stockholm Conference 1972 (#17). It is also responsible to EHC partly for acting as a kind of a secretarial office. It prepares necessary regulations, standards or criteria by coordinating and consulting other relevant ministries and offices, and presents the regulations, etc. to EHC for approval. The organization of DOE is charted in **Fig. 4.1.1**. The Director is one of Vice Presidents of Iran, as of September, 1999.

DOE has its annual budget allocated for current and development expenditures. In addition, as its financial support, DOE was able to supervise equivalent amounts of 0.001 % of industries sales during the First Cultural Social Economical Development Plan (1989 - 1994) (#01). Also DOE will receive 50% or maximum of one billion Rials annually from the fines specified in the Air Pollution Control Act of 1995 to implement the Act.

The annual budget of the environmental protection expenditure is in the range of 36.8 - 56.2 billion Rials for 1994 to 1999 as in **Table 4.1.2** (#16). Total environmental protection expenditure is planned to grow annually at average 8.8%. However, its growth rate is smaller than the average annual growth rate of the whole budget. Accordingly, the distribution of the environmental protection expenditure is planned to become smaller than 0.1% of the whole budget from 1998. This reduction is resulted from greater growth of the total development expenditure budget. The growth of the current environmental protection expenditure is almost equal to the one of the current total expenditure of the budget.

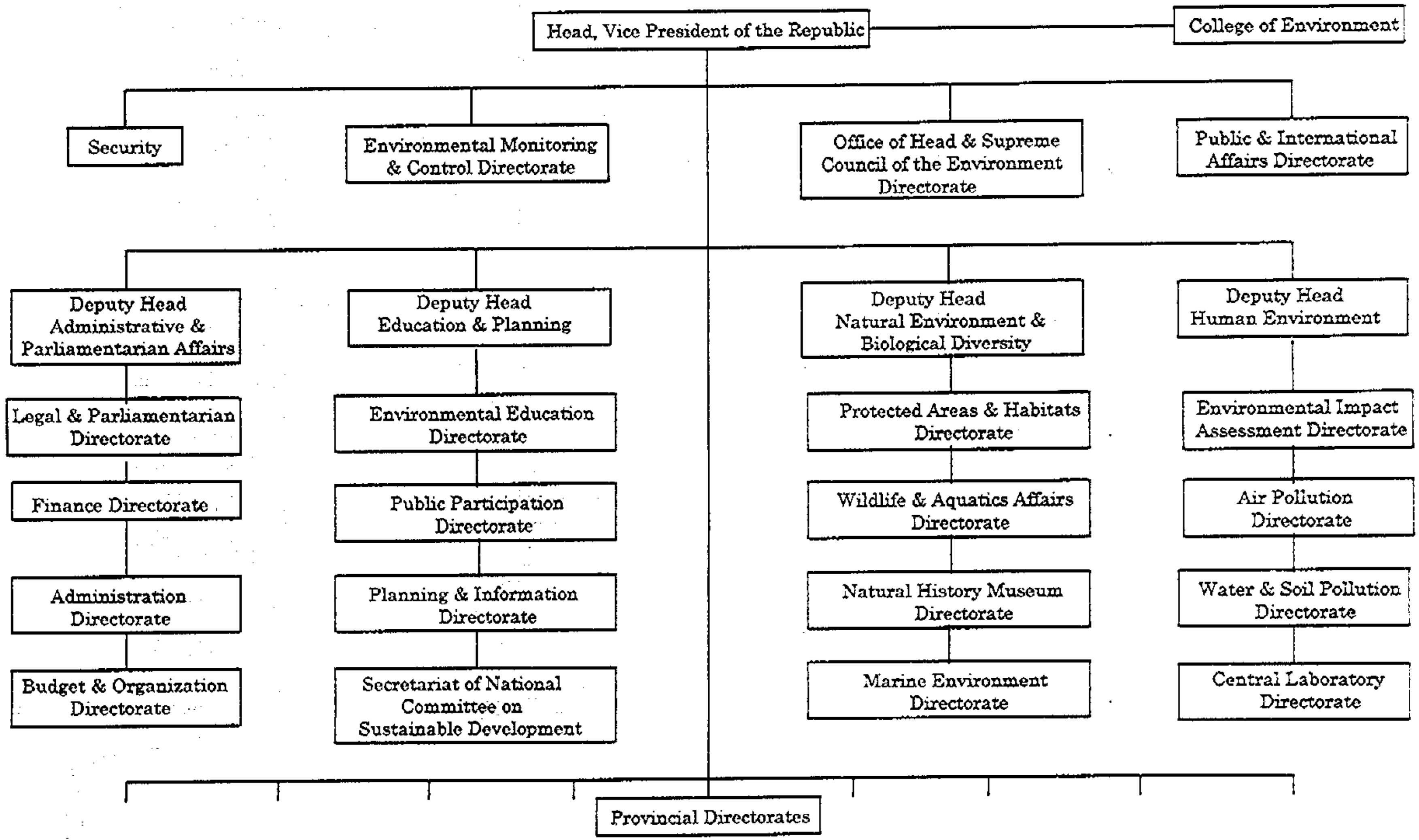


Fig. 4.1.1 Organization of Department of Environment

Reportedly, DOE's budget in 1997 is 8.5 billion rials for the current expenditure and 17 billion Rials for the development expenditure (#99, 2/8/98).

Table 4.1.2 Environmental Protection (EnP) Expenditures in Annual Budget

	1994	1995	1996	1997	1998	1999	Growth %
Current EnP Expenditure	13.4	14.5	15.7	17.2	19.5	22.2	10.6
Development EnP Expend.	23.4	24.1	26.8	29.5	31.6	34.0	7.8
Total EnP Expenditure	36.8	38.6	42.5	46.7	51.1	56.2	8.8
Current Total Expenditure	18,831	22,596	24,385	26,118	28,423	31,635	10.9
Develop. Total Expenditure	11,219	13,798	16,911	20,615	24,515	29,190	21.1
Whole Expenditure Budget	30,050	36,394	41,296	46,733	52,938	60,825	15.1
EnP % in Whole Budget	0.122	0.106	0.103	0.100	0.097	0.092	--

Source (#16) Unit billion Rls. (Except %)

DOE's roles for air pollution are a) source identification, b) determination of ambient air quality, c) inspection and monitoring, d) technical assistance, and e) others, according to the Air Pollution Control Act.

DOE announced that its major projects in 1998 would be a public education campaign on environmental issues, conducting ecological and biological studies as well as environmental evaluations, equipping relevant centers, carrying out studies on natural disasters, marine environment, and water and soil pollution (#99, 2/8/98). On February 18 1998 the Clean Air Day, President Khatami took a public bus from his house to the office to enjoy a talk with ordinary people and to demonstrate his intention of environmental protection by less car use and energy saving.

4.1.3 Air Pollution Control Act

Air Pollution Control Act was originally a rule in 1975 to provide for requirements of the Environmental Protection and Enhancement Act of 1975 in relation to air pollution. The rule was enacted as the Act in 1995.

This Act (#35) is composed of 6 sections and 38 articles. The sections are titled as 1) General, 2) Motor Vehicles, 3) Factories, Workshops and Power Plants, 4) Business, Domestic, and Miscellaneous Sources, 5) Punishments, and 6) Miscellaneous Regulations.

Section 3 has the most concern of the Study. It contains 10 articles from Article 12 to 21. Items in Section 3 related to power plants are as follows:

1) Construction of power plants requires compliance with the regulations and standards drafted by DOE and approved by the Board of Ministries, in regards to their location (Article 13, Note1 & 2).
2) Activities and operations of power plants which produce sources of air pollution above the permitted levels are forbidden (Article 14).
3) DOE will identify power plants which pollution is higher than the permitted levels set in the environmental standards. The owners will then be given until a specified time, as determined by DOE with the help and cooperation of related organizations, to take action in relation to the elimination of the pollution, which may or may not require temporary closure of their work and activities (Article 15). DOE is charged with determining, for every region, clean air standards as well as standards for polluting emissions produced by the factories and workshops of that region. The permitted levels (environmental health standards) will be approved by EHC (Article 15, Note 2).
4) If the owners of the power plants do not modify their activities so as to reduce pollution within the allocated period, their activities will be curbed (Article 16), and the owners will be penalized according to this law. Managers of power plants who ignore the notice, will have their cases reviewed by special disciplinary committee (Article 16, Note).
5) In an emergency situation or under special atmospheric conditions, EPA has the power to the temporary closure of factories and workshops (Article 17).
6) Power plants must allocate at least 10 % of their area to greenery and tree (Article 19).
7) Power plants are required to use fuels and combustion systems that reduce the level of air pollution (Article 20).
8) Owners and responsible parties of polluting factories and workshops which act against Articles 14, 16 and 17, will be sentenced, for the first offense, a fine of 500,000 to one million Rials. If repeated, they will be sentenced to jail from 2 to six months and 700,000 to two million Rials (Article 30).

All the Articles in this Act have clearly separated Factories, Workshops and Power Plants in the description. From this style of writing, three items are notable:

a) Article 17 implies that the power industry is not subject to the closure term because it is a lifeline to the public.

b) Article 15 seems related to national and regional environmental standards. Although the national standards regulate emission levels of power plants, Note 1 of the Article does not mention that the regional ones can regulate the levels of the power plants.

c) Penalty on the owners of power plants mentioned in Note of Article 16 will not be imposed, according to Article 30 which is for owners of factories and workshops.

There are two bodies which approve regulations and so on determined or drafted by DOE in the Act. They are EHC and Board of Ministries. The second one does not seem well organized in its functions, rights, responsibilities, duties, etc.

Article 36 of the Act states that the regulations pertaining to this law will be prepared by DOE (and in some cases, with the cooperation of other relevant organizations) within three months after approval of this law. The approval was on April 23, 1995. However, there are many remained to be implemented.

4.1.4 Energy Management Law

Energy Efficiency Office under the Deputy Minister for Energy Affairs, MOE, drafted a law concerning with improvement of energy efficiency and presented it to the cabinet which would be ready to pass it to the Parliament for authorization (as of September 1999). The draft intends to install an energy manager in each organization which consumes more than 2 MW demand annually. It also stipulates that each related ministry should specify energy efficiency of each power consuming equipment, such as building appliances, industry apparatuses, and transportation vehicles.

Energy Efficiency Office itself has been operating a laboratory for testing energy consumption of house appliances, air conditioners, etc. It has published various educational pamphlets of energy saving for school children, citizens, industrial people, etc.

4.1.5 Water Pollution

There are several laws promulgated for controlling water pollution (#17) as below.

1) Water Distribution Act of 1982 - makes the owner, operators of water wells and canal systems responsible for preventing water pollution, and water supply companies to have their water purification and waste water treatment systems approved by the Government.

Ground water extraction by wells with discharge of more than 25 m^3 per day require permit from DOE to guard against over exploitation of the aquifer.

2) Water Pollution Control Rule of 1984 - provides the enforcement mechanism for water pollution control provisions of the Environmental Protection and Enhancement Act of 1975, focusing on monitoring, inspection and relocation of polluting industries and other sources. DOE is given the responsibility for enforcement, with the cooperation of other agencies. Sewage discharge standards were set by the EHC in 1993 following the recommendations of DOE.
3) Water and Sewage Companies Law of 1990 - gives the responsibility for the collection, treatment and disposal of sewage to each Province's water and sewage company.

4.1.6 Second Five Year Development Plan

The Iranian Second Five Year Development Plan (#16) indicates the strong direction of environmental protection and optimal utilization of natural resources in its Objective No. 10th (within 16 objectives) with nine basic policies. The policies are summarized as follows:

1) conserve, renew, and properly exploit natural resources,
2) enhance operations related to detailed exploration, equipment and preparation of the mines needed by industries,
3) exploit mines to supply required raw material and to replace imported materials,
4) make easy for participation of non-governmental mine developers,
5) increase water supply through completion of irrigation and drainage networks, etc.,
6) establish necessary environmental regulations, standards, criteria and indexes, and reform existed legal frameworks on the basis of the latest scientific findings and in accordance with Iran's conditions and possibilities,
7) utilize energy resources optimally by modification of existing consumption pattern, increasing efficiency and use of clean substitutes,
8) conserve and rehabilitate renewable natural resources; preserve rare flora; control desertification; reclaim desert lands; prevent soil erosion and pollution, various pollution of air, water, and marine; prevent destruction of wildlife habitats; exploit properly mineral resources in compliance with environmental regulations, and finally
9) apply optimally pesticides and fertilizers in farming; use biological techniques for controlling pests with a view to reduce reliance on poisons.

To implement the Second Five Year Plan, a law concerning the Plan was promulgated on

December 29 1994. Following are quoted in full of Notes 82 and 83 of the Law (#21), with notations in parentheses by the JICA Team.

[Quote] Note 82

a. In the course of 2nd Plan all the economic and social activities shall be carried out with due regard to the environmental considerations and for this purpose the implementation of following items is binding:

   1. The manufacturing and servicing large projects and plans shall before execution and in the stage of feasibility and location studies be assessed from the viewpoint of environment preservation on the basis of patterns approved by the Supreme Council of Life Environment Preservation (= EHC).

   2. The fulfillment of any industrial and mineral operation shall be with due regard to the goals of stable development, within the criteria of living environment standards.

   3. The exploitation of country's natural resources shall take place upon living environment's potential capability and the tolerable capacity of environment, so that while making the right use of natural resources the requirements of balancing and the suitability of living environment will be assured.

   4. The utilization of energy in the country shall be made by the revision in the consumption pattern and decrease of fuel pollution.

b. In the course of 2nd Plan, the government shall take necessary steps for reducing the air pollution of Tehran, Mashad, Tabriz, Ahwaz, Arak, Shiraz and Esfahan to the standard of World Health Organization.

Executive regulations of this Note will be prepared by the Organization of Living Environment Preservation (= DOE), upon cooperation with the concerned departments and approved by the Council of Ministers.

Note 83

For the purpose of prevention of and the removal of water sources polluted by industrial sewage, the industrial units and factories located in the towns and industrial complexes shall take measures for the establishment and commissioning of collection and transfer networks, as well as the installations of filtration of industrial sewage, based upon the standards enunciated by the Organization of Living Environment Preservation (=DOE) and through the participation or supervision of the provincial water and sewage companies. [Unquote]

Implementation of EIA, sustainable development, and energy saving are main subjects in the

Note 82. The EIA formats, criteria of living standards, etc. given in the Note are allegedly under preparation. Seven large cities including Tabriz and Esfahan - the target areas of the Study are mentioned as for reduction of air pollution.

4.2 Ministry of Energy (MOE)

MOE is composed of seven Deputies as follows with major activities in parentheses:

a) Deputy of Energy Affairs
b) Deputy of Power Affairs (Power Generation, Distribution)
c) Deputy of Water Affairs (Dam, Rivers, Flood Management, Supply of Potable Water)
d) Deputy of Municipal Waste Water Affairs (Collection and Treatment)
e) Deputy of Planning and Monitoring Affairs (Demand and Forecast)
f) Deputy of Recruit, Education and Personnel Affairs
g) Deputy of Support and Parliament Affairs

Notable here is that the Ministry is responsible not only for electricity supply but also potable water supply and municipal waste water treatment.

Table 4.2.1 (#04) shows the organization under the Deputy of Energy Affairs, which contains the Environment Department in the Energy Planning Office, the counterpart of this Study. The Department was established in 1994 to deal with the environmental issues. It has staffed with 7 specialists in the middle of 1999. Projects accomplished in the Department (#22) are a) Development of mathematical model for environment of watershed basin of Amirkabir and Sefidrud Dams, b) Evaluation of present status of power plants and preparation of suitable strategy for site selection, c) Preparation of a book on environmental effects of power plants, d) Marine pollution due to oil export and response to oil pollution, etc.

Also the Department is ready to take part in management of power plants solid and liquid waste effluents, power plant's site selection, its social costs, EIA of hydropower dams, health of artificial lakes, etc. With regard to air pollution, the current JICA Study is substantially the first experience of the Department.

Table 4.2.1 Organization of Deputy for Energy Affairs in Ministry of Energy (#04)

	Office	Department
Deputy for Energy Affairs	Energy Information Center	Documentation & Information Center
		Data Bank & Computer Center
		Data Collection & Survey
	Energy Planning Office	Economical Studies
		Energy Balance
		Planning
		Environment - (Sections) - Environmental Planning & Management - Environmental Impact Assessment - Air, Soil & Water Pollution
	Energy Efficiency Office	Load Management
		Transportation
		Power Plants & Refineries
		Residential, Commercial, Agricultural
		Industry
	New & Renewable Energy Office	Wind & Solar
		Hydro-energy
		Geothermal
		Biomass

Chapter 3 has already described the organization in Deputy of Power Affairs which has many affiliates in relation with electric power generation. Among the affiliates, Tavanir is the operator of all power plants including the two target power plants: Tabriz and Esfahan.

Also affiliated to the Ministry, there are non-profit 'cum-companies' which are responsible for execution of projects interested by the Ministry. They are required to increase capacities of the Ministry to meet ever-progressing and diversifying technologies related with energy.

Iran Center for Energy Studies (ICES) is one of three companies affiliated to the Deputy of Energy Affairs. Two other cum-companies are for energy conservation and new energy. ICES's share holders are Power Research Center (MOE), Iran Power Generation and Transmission Company (Tavanir), and Tehran Regional Power Company (#27). ICES has 75 experts and some of them carry out projects, such as this Study, assigned by the Environment Department of MOE. In addition to the environmental issues, ICES handles projects related to the fields of economics, gas, oil, electrical and mechanical, renewable energy, energy conservation and management, etc.

4.3 Local Municipalities

There is a branch of DOE (the President's Office) in all 28 provinces. Budget of each DOE branch is allocated by DOE Headquarters. With the limited manpower, budget and equipment, each DOE branch is concentrating for its local interests in monitoring, negotiating with pollution sources for reduction, establishing local standards of ambient air quality, and trying to do else.

Within the two targeted regions, the Eastern Azarbayjan DOE branch has kept operation of 3 air monitoring stations for more than 15 years in Tabriz and recommending the power plant for switching its fuel to natural gas, and the Esfahan DOE branch is now concentrating on monitoring CO concentration once in a week at the busiest intersection in Esfahan. Ministry of Health is going to operate one intermittent monitoring (SO_2 and TSP) station at Esfahan and report its data to GEMS (Global Environmental Monitoring System of United Nations), in addition the Ministry's three such stations in Tehran.

As Tehran is one of the mostly polluted mega-cities in the world (#107), Municipality of Tehran installed Air Pollution Control Company under the organization of its Deputy Mayor on Transportation and Traffic Affairs to alleviate air pollution allegedly caused by mobile sources. Municipality of Tehran is operating three automatic air quality monitoring stations and one mobile station in the city. In Tehran there are six similar stations operated by DOE Headquarters and one station by Ministry of Health & Medical Education.

4.4 Ambient Quality and Emission Standards

(1) Air Quality

Table 4.4.1 shows Iranian air quality standards (#90) based reportedly on WHO Guidelines and authorized by EHC.

However, the JICA Team obtained the current WHO Guidelines (#61) as given in **Table 4.4.2.** There are substantial discrepancies in values in two tables. The law concerning the second five year development plan (#21) has stated that WHO guidelines are targeted as air quality in Tehran, Tabriz, Esfahan, and other four big cities.

Table 4.4.1 Iranian Air Quality Standards (#90)

Pollutants	Averaging Periods	Primary Standards[2]		SecondaryStandards[3]	
		μg/m³	ppm[4]	μg/m³	ppm[4]
CO	Maximum in 8 hours	10,000	9	10,000	9
	Maximum in 1 hour[1]	40,000	35	40,000	35
SO_2	Annual average	80	0.03	60	0.02
	Max. in 24 hours[1]	365	0.14	260	0.1
	Max. in 3 hours[1]	--	--	1,300	0.5
Non-methane hydrocarbons	Max. in 3 hours of 6 to 9 am[1]	160	0.24	160	0.24
NO_2	Annual average	100	0.05	100	0.05
SPM	Annual average	75	--	60	--
	Max. in 24 hours[1]	260	--	150	--
Photo-chem. Oxidants	Max. in 1 hour[1]	160	0.08	160	0.08

Note 1) not to be exceeded for more than once per year
2) for public health, 3) for public welfare, 4) no specific standard temperature given to convert volume to weight and vice versa, presumably to be 20 or 25℃

Table 4.4.2 WHO Air Quality Guidelines for Pollutants Concerned (#61) for European Community & in Parentheses for Other Countries

Pollutant	Hourly Mean	Daily Mean	Annual Mean
TSP*2)	-	120 (150-230)	- (60-90)
BS*1)*2)	-	125 (100-150)	50 (40-60)
SPM*2)	-	70	-
SO_2	350	125*4) (100-150)*4)	50*3) (40-60)*3)
NO_2	400 (190-320)*2)	150	-

Unit: μg/m³(25℃)

Note 1) particulates typically included respirable particulates smaller than 4.5μm in aerodynamic diameter
2) not to be exceeded for more than one day per year
3) arithmetic mean
4) 98 percentile of all daily values taken throughout the year. Should not be exceeded more than 7 days a year.

In order to let the citizen be easily aware air pollution levels, Municipality of Tehran has set up Pollutant Standards Index (PSI) and publicized it on a board at a busy intersection together with the current concentration of SO_2, NO_2, CO, O_3 and SPM monitored with automatic analyzers. PSI is a number converted from the one of the measured concentrations which has the highest potential health effect within the five pollutants at the moment and which approximately corresponds to the one having the highest ratio to its air quality standard within the five pollutants. PSI 100 is the most important number, since it corresponds to one of the air quality standard at daily or hourly basis. PSI below 50 means air is clean. If it is above 100, 200, or 300, air is respectively unhealthy, very unhealthy, or hazardous.

In the middle of December 1998, Tehran experienced sever air pollution caused by carbon monoxide, indicating PSI over 300. Ministry of Health & Medical Education issued the warning for the first time in Tehran, and the Traffic and Transportation Department enforced emergency traffic restrictions of passenger cars by plate numbers (#99, 12/16/98).

(2) Stack Emission

There is no ratified national or local emission standards for any pollutant from any industrial stack gas in the knowledge of the JICA Team. A basic policy of the Second Five Year Plan stated that the necessary standards had to be drawn up (#16). DOE drafted the emission standards (#90) and published them for discussion and for basis of local standard preparation. **Table 4.4.3** is the drafted emission standards of power plant.

Table 4.4.3 Drafted Emission Standards of Air Pollutants from Power Plants(#90)

Pollutants	units	Primary Standard	Secondary Standard	Remarks
Sulfur dioxide	ppm	800	800	
Carbon monoxide	mg/m^3	150	150	
Nitrogen oxides	ppm	350	350	
Soot	mg/m^3	150	350	fuel oil burning
Smoke Index	%	20	20	

Note: 1)No description given on O_2 contents, temperature and pressure of exhaust gases
2)Refer to Note 2 & 3) of **Table 4.4.1** for the Primary and Secondary Standards.

(3) Waste Water Quality

Waste water quality standards were given in a pamphlet prepared by DOE Headquarters (#90). **Table 4.4.4** is an extract from 52 pollutants given in the pamphlet.

As the quantitative target of river water quality, the YEARBOOK (#51) described that 14 rivers, including Zayandehrud of Esfahan, should have BOD of 10 mg/liter by the end of the Second Development Plan, gradual reduction from 40 - 50 mg/liter values in 1993. BOD of a power plant waste stream should be less than 10 mg/l instead of 30 as given in Table 4.4.4, if the stream flows in Zayandehrud.

Table 4.4.4 Maximum Permissible Concentration of Pollutants in Waste Stream

(Extract of #90)

Pollutants	Units	Waste Water discharged to		
		Surface Water	Absorption wells	Irrigation Use
BOD	mg/l	30	30	100
COD	mg/l	60	60	200
Color	Unit	75	75	75
DO	mg/l	2	--	2
Ammonia	mg/l as NH_4	2.5	1	0
pH	Unit	6.5 - 8.5	5 - 9	6 - 8.5
TSS	mg/l	40	--	100
Calcium	mg/l	75	--	--
Cadmium	mg/l	0.1	0.1	0.05
Free Chlorine	mg/l	1	1	0.2
Chloride	mg/l	600	600	600
Cyanamide	mg/l	0.5	0.1	0.1
Cobalt	mg/l	1	1	0.05
Chrom (6)	mg/l	0.5	1	1
Cupper	mg/l	1	1	0.2
Fat in oil	mg/l	10	10	10
Floride	mg/l	2.5	2	2
Formaldehyde	mg/l	1	1	1
Iron	mg/l	3	3	3
Lead	mg/l	1	1	1
Magnecium	mg/l	100	100	100
Mercury	mg/l	nil	nil	nil
Nickel	mg/l	2	2	2
Phenol	mg/l	1	nil	1
Sulfate	mg/l	400	400	500
Sulfide	mg/l	3	3	3
Sufite	mg/l	1	1	1
Vanadium	mg/l	0.1	0.1	0.1
Zinc	mg/l	2	2	2

CHAPTER 5 METEOROLOGICAL OBSERVATION

5.1 Introduction

Meteorological observation in this Study consists of Upper Layer Observation from the ground level to a height of 1500 m and Surface Observation on the ground level. The Upper Layer Observation had been carried out in each four season, and the Surface Observation had been carried out continuously in one year.

5.2 Methods

5.2.1 Methods of Upper Layer Observation

The Upper Layer Observation at Tabriz and Esfahan Power Plants had been carried out in each three days (72 hours) in each four season. Items observed are wind directions and speeds and air temperatures. Equipment for this observation is the T-5 series in the JICA equipment list shown in **Appendix 1-3**. Details of the observational methods are described in **Appendix 5-1**.

(1) Upper Wind Observation (Pilot Balloon Observation)

Upper wind observation from the ground up to a height of 1500 m had been carried out on every one hour by Pilot Balloon and Balloon Theodolite. The Pilot Balloon is a simple rubber balloon (weight: 20 g) filled with Helium gas and has a buoyancy force of 133 g exactly. The Pilot Balloon released from the ground, moves upward with a constant ascend speed of 200 m/min., and finally bursts at a height of about several thousand meters. The observer measures the elevation angle and azimuth angle of the ascending Balloon visually by Balloon Theodolite at a constant time interval of 15 second. These angle data are transmitted to a personal computer. It calculates the coordinates of the ascending Balloon, the upper wind direction and upper wind speed from these coordinates at the constant height interval of 50 m.

(2) Upper Air Temperature Observation (Low-Level Radio Sonde Observation)

Upper air temperature observation from the ground up to a height of 1500 m on every three hour had been carried out by the Low-Level Radio Sonde System, which has total weight of 300 g and consists of four parts: Balloon, Nylon Rope, Parachute and Sonde Oscillator. The Low-Level Radio Sonde released from the ground, moves upward by the buoyancy of 520 g with an ascend speed of 300 m/min. and measures upper air temperature, humidity and pressure continuously by each sensor. These data are transmitted by a radio wave of 1680 MHz to a data processor, and converted to values of each standard height (from the ground to 1500 m at 50 m intervals).

5.2.2 Methods of Surface Observation

Surface Observation at Tabriz and Esfahan Power Plants and their surroundings (see **Fig. 1.2.1** and **1.2.2**) had been carried out continuously in one year at each plant from June 1998. Items and method of surface observation are shown in **Table 5.2.1**. Equipment for this observation is the T-4 and E-4 series in JICA equipment list shown in **Appendix 1-3**.

Table 5.2.1 Items and Methods of Surface Observation

Items	Methods
Wind Direction and Speed	Measured by Vane and Anemometer; Data transmission telemetrically - Direction by photo-encoder and Speed by photo-interrupter
Temperature	Platinum resistance electric thermometer
Solar Radiation	Electric Pyranometer with a thermocouple covered by a glass dome
Net Radiation	Electric Net Radiometer with two thermocouples covered by polyethylene domes

Furthermore, atmospheric stability was obtained from wind speed and solar radiation or net radiation for the dispersion simulation.

5.3 Results and Evaluations of Upper Layer Observation

5.3.1 Results

(1) Tabriz

The upper layer meteorology had been observed at the Tabriz Power Plant in June 1998, August 1998, October 1998, and January 1999. All the results are compiled by the local computer and profiled in **Appendix 5-2**. Examples of the results are graphically shown in **Fig. 5.3.1a** and **b**. Features of these results are pointed out in **Table 5.3.1**.

Wind was mainly in the east, and in winter it was frequently in the west. Wind speed was generally higher at higher altitude. In several cases, however, wind speed was the strongest at the height of around 1000 m. Upper air temperature was mainly falling from the ground to upper layer in day time, and lapse rate of temperature was very large near the ground level. The ground inversion layers were observed frequently in the night.

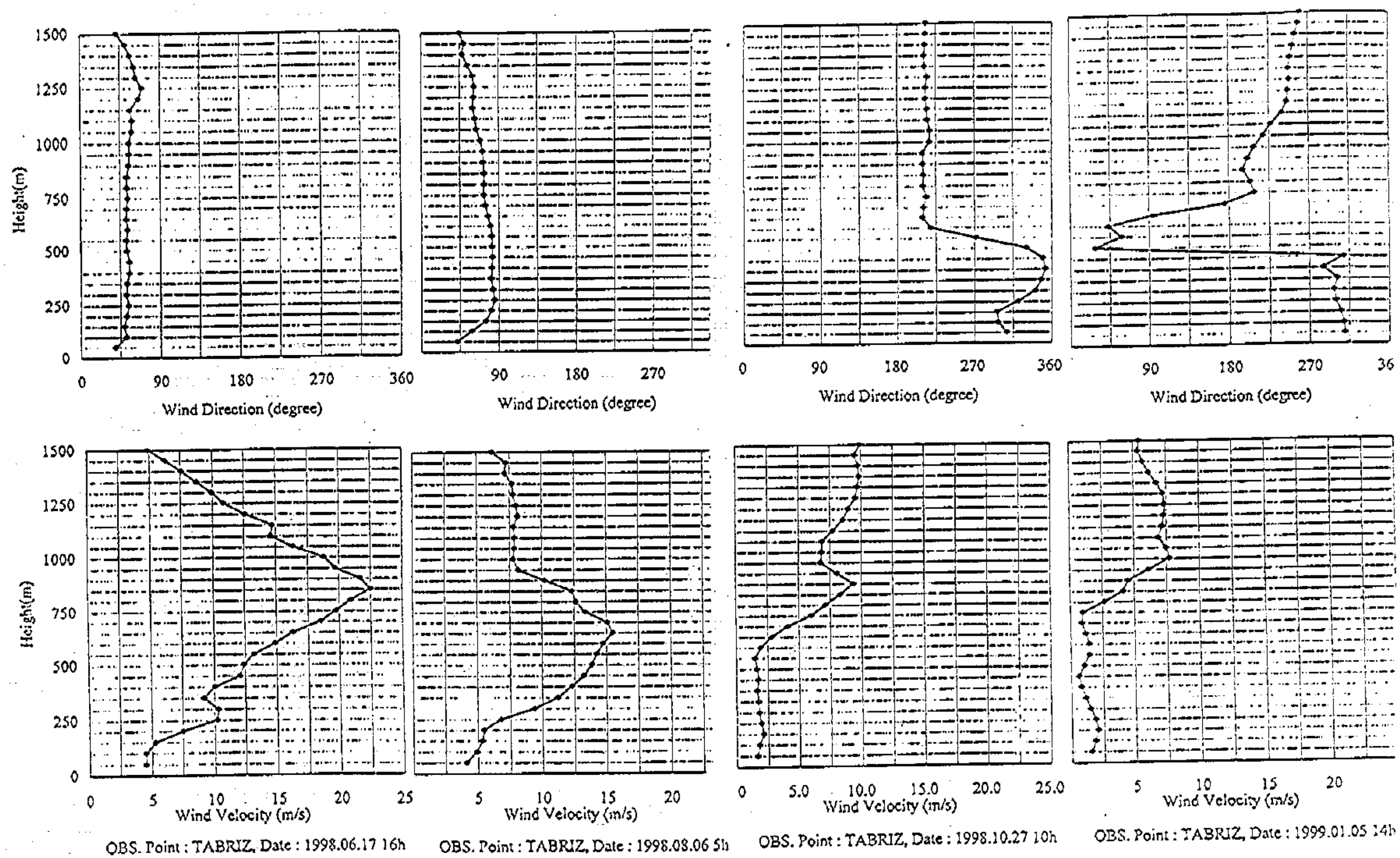


Fig. 5.3.1a Examples of Upper Layer Observation Data - Tabriz (0 and 360° = North)

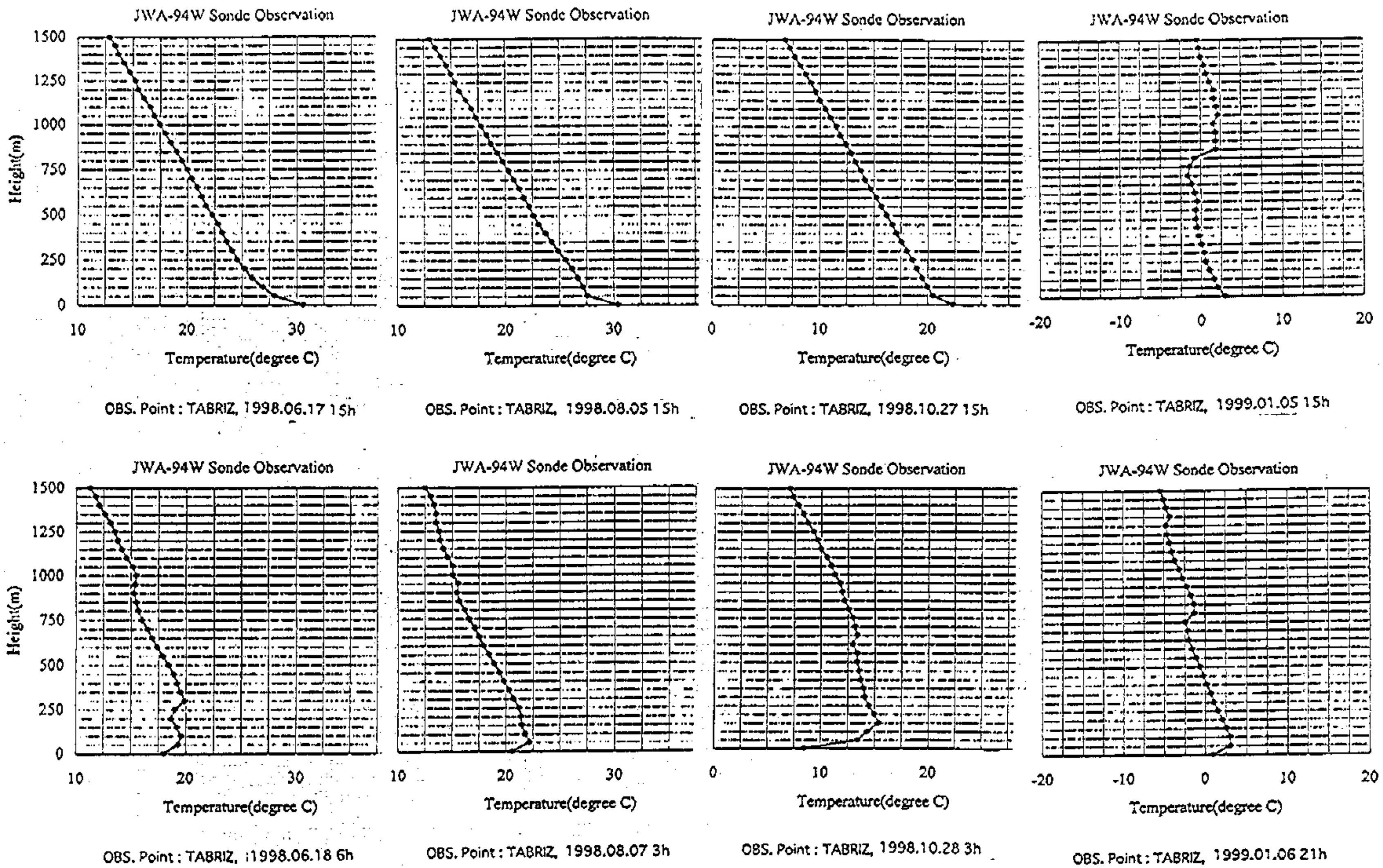


Fig. 5.3.1b Examples of Upper Layer Observation Data - Tabriz

Table 5.3.1 Feature of Upper Layer Meteorology at Tabriz

	Wind		Air Temperature	
	Direction	Speed	Daytime	Night
Spring	Mainly between in the north and east	Increasing by the heights; The maximum more than 20m/s around at 1000 m	Large temperature lapse rate near the ground level	Inversion layers near the ground level
Summer	Mainly between in the north and east	Increase up to around at 500 m by the heights with the maximum more than 20 m/s, and decrease in the upper layer higher than about 1000 m	Very large temperature lapse rate near the ground level	Moderate inversion layers near the ground level
Autumn	Mainly between in the south and west; Between in the west and north, or the north and east in the upper layer above 500m	Increasing with the heights from the ground, but not so strong	Moderate temperature lapse rate	Large inversion layers near the ground level
Winter	Variable, mainly in the west	Increasing with the heights from the ground, but not so strong	Small temperature lapse rate. Inversion layer even in the upper layer	Small inversion layers near the ground and also in the upper layer

(2) Esfahan

The upper layer meteorology had been observed at the Esfahan Power Plant in February 1998, June 1998, August 1998 and October 1998. The observed data are accumulated in the local computer and profiled in **Appendix 5-2**. Examples of results are shown in **Fig. 5.3.2a** and **b**. These results are featured in **Table 5.3.2.**

Wind was variable, but mainly in between the east and the south and it was mainly in the west in winter. Wind speed was mainly increasing from the ground to upper layer. Upper air temperature was mainly falling from the ground to upper layer in day time, and lapse rate of temperature was very large near the ground level. In night time, the ground inversion layer was formed and its maximum temperature difference was about 12 degree C. In several cases, the ground inversion layer disappeared temporarily at near midnight, and formed again later.

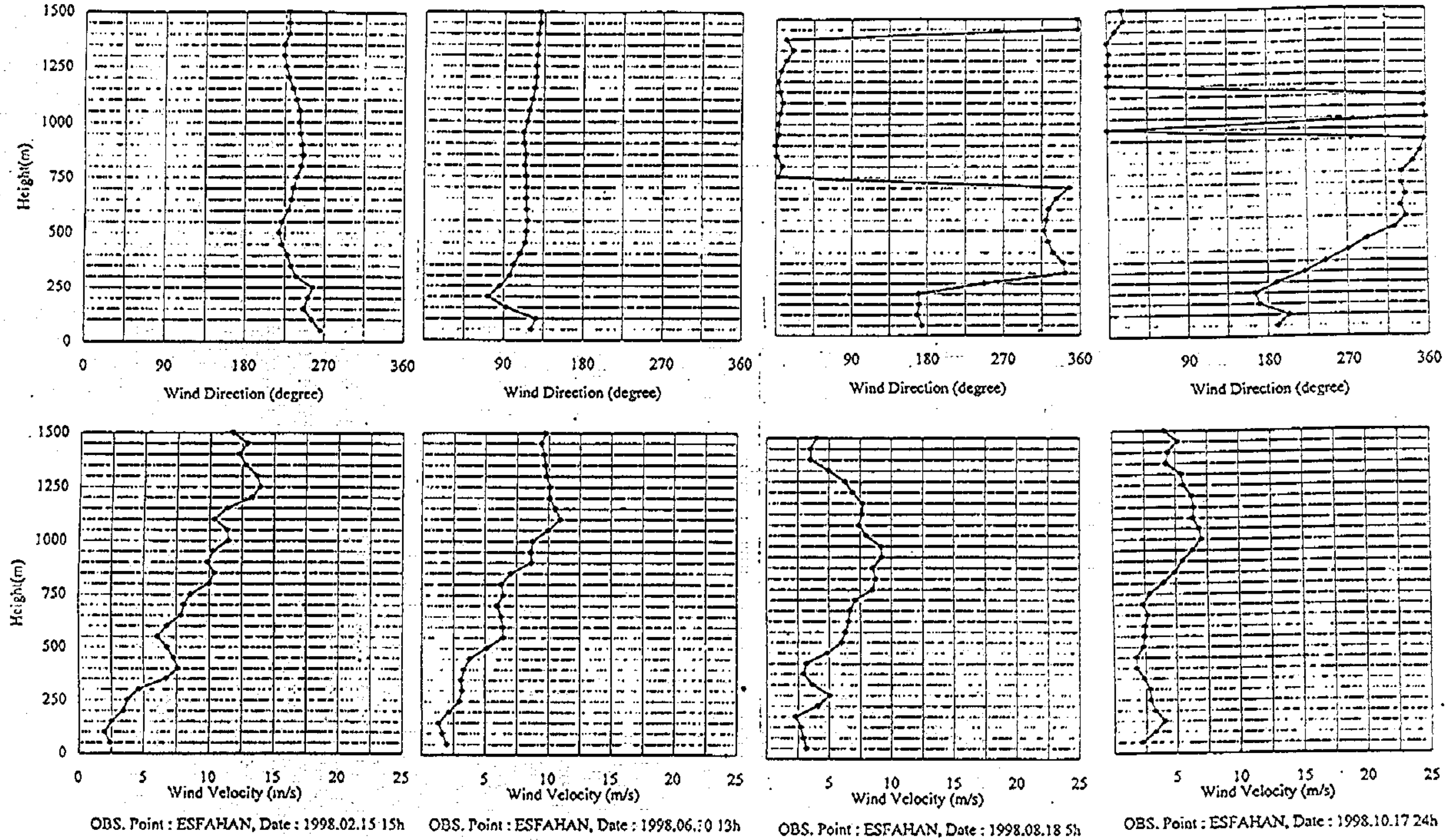


Fig. 5.3.2a Examples of Upper Layer Observation Data - Esfahan(0 and 360° = North)

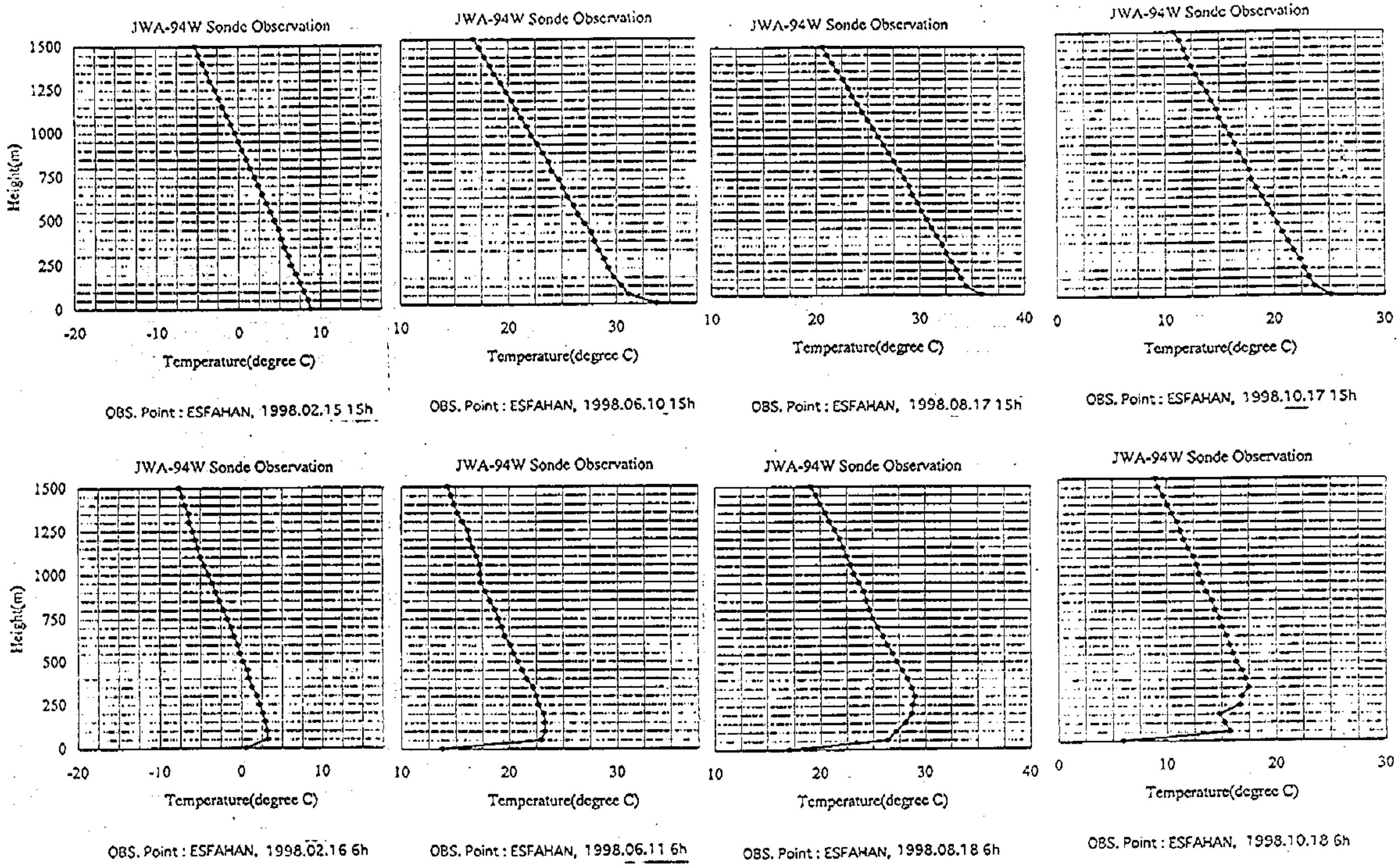


Fig. 5.3.2b Examples of Upper Layer Observation Data - Esfahan

Table 5.3.2 Feature of Upper Layer Meteorology at Esfahan

	Wind		Air Temperature	
	Direction	Speed	Daytime	Night
Spring	Mainly between the east and the south	Increasing by the heights; The maximum more than 20 m/s after the sunset	Very large temperature lapse rate near the ground level and large even in upper layer	Large inversion layers near the ground level; In several cases, temporal disappearance of the layer at midnight, and appearance again later
Summer	Variable	Increasing by the heights though rather weak	Large temperature lapse rate near the ground level	Large inversion layer near the ground level with its maximum temperature difference at about 12 deg C. In several cases, temporal disappearance of the layer at midnight, and appearance again later
Autumn	Variable	Mainly weak	Large temperature lapse rate near the ground level	Large ground inversion layer with its maximum temperature difference at about 12 deg C
Winter	Mainly between the south and the west	Mainly weak	Fairly large temperature lapse rate near the ground level	Inversion layer near the ground level

5.3.2 Evaluations

(1) Upper wind

Fig.5.3.3 a and b, and **Fig.5.3.4** show wind roses and average wind speed in several levels of the upper layer. Wind was mainly in the west by influence of "the prevailing westerlies of the Earth" at both sites in winter. In spring, wind was mainly in the east by influence of an anticyclone covering the Caspian Sea. In summer at Tabriz, wind was also mainly in the east by the same effect of the Caspian Sea. At Esfahan in summer, it was variable by a high pressure system covering the central part of Iran. In autumn, wind was mainly in the south-west at Tabriz though somewhat variable, and in the south-east at Esfahan by a high pressure system covering the eastern to the southern parts of Iran. Wind speed generally increased from the ground by heights at both of Tabriz and Esfahan.

(2) Upper Air Temperature

Average upper air temperatures in several levels are shown in **Fig.5.3.5**.

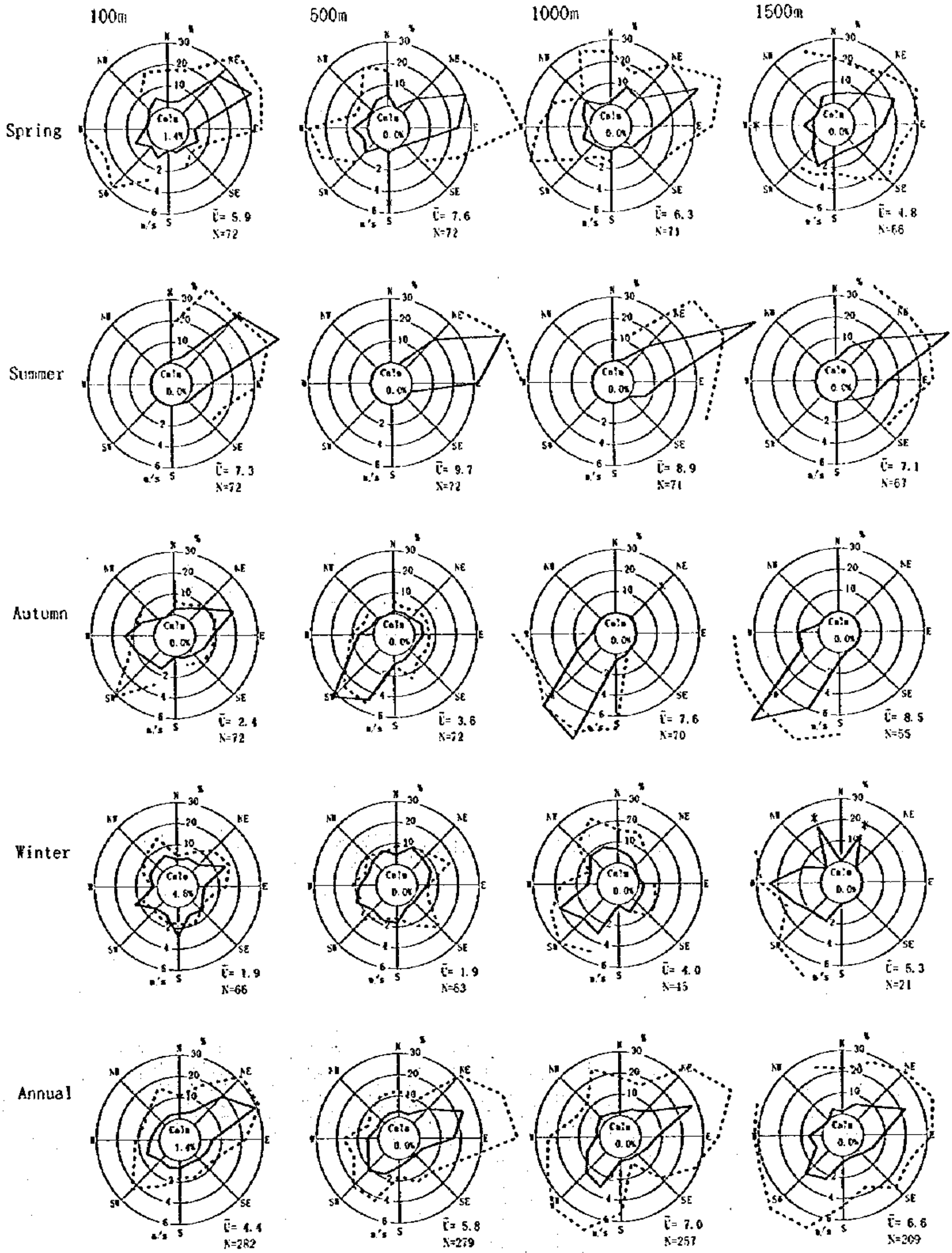


Fig. 5.3.3a Upper Layer Wind Rose Diagram – Tabriz

——— Wind Direction Frequency
······· Wind Speed Average
Calm ≦ 0.4 m/s

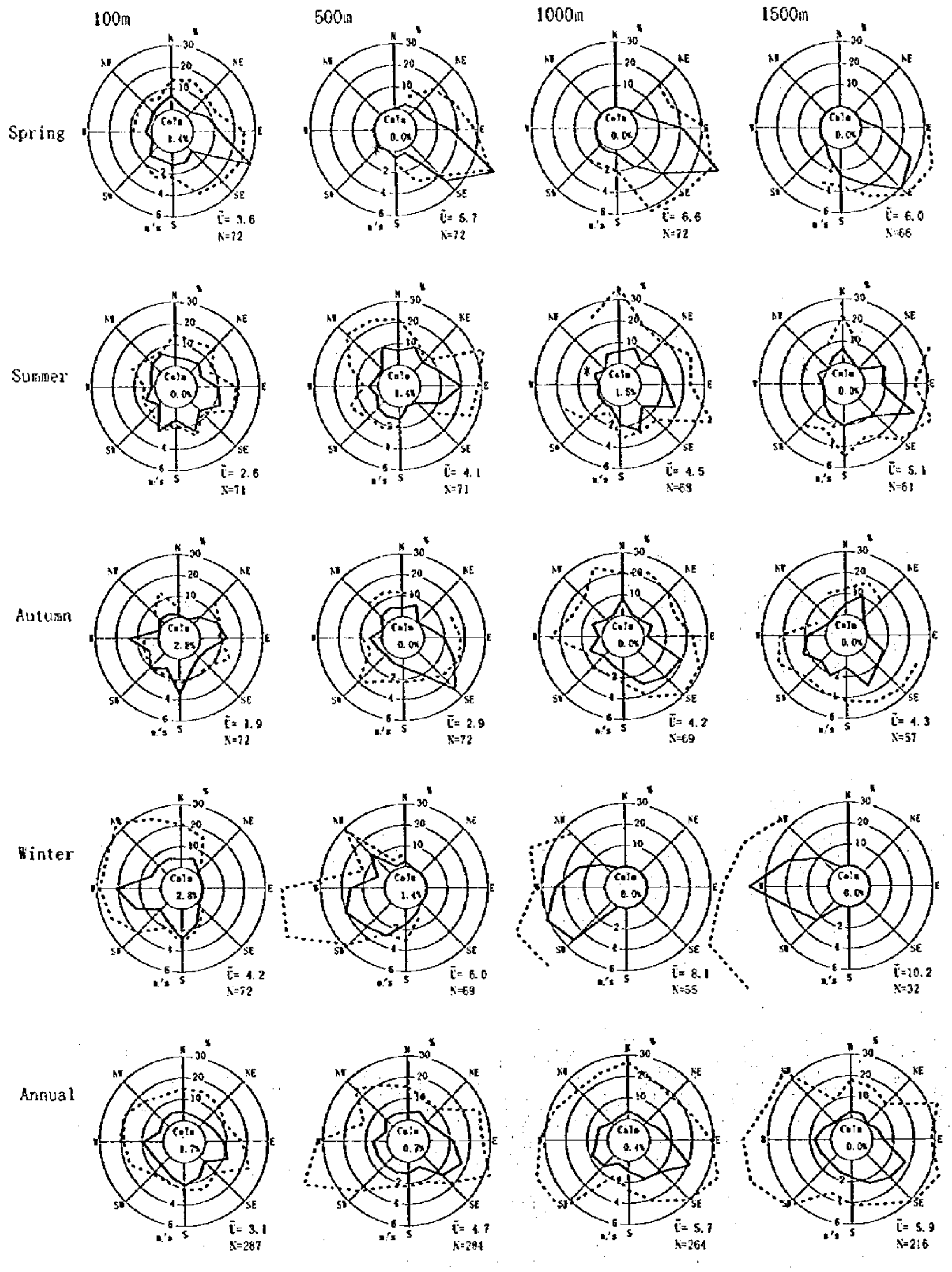


Fig. 5.3.3b Upper Layer Wind Rose Diagram - Esfahan

——— Wind Direction Frequency
······ Wind Speed Average
Calm ≦ 0.4 m/s

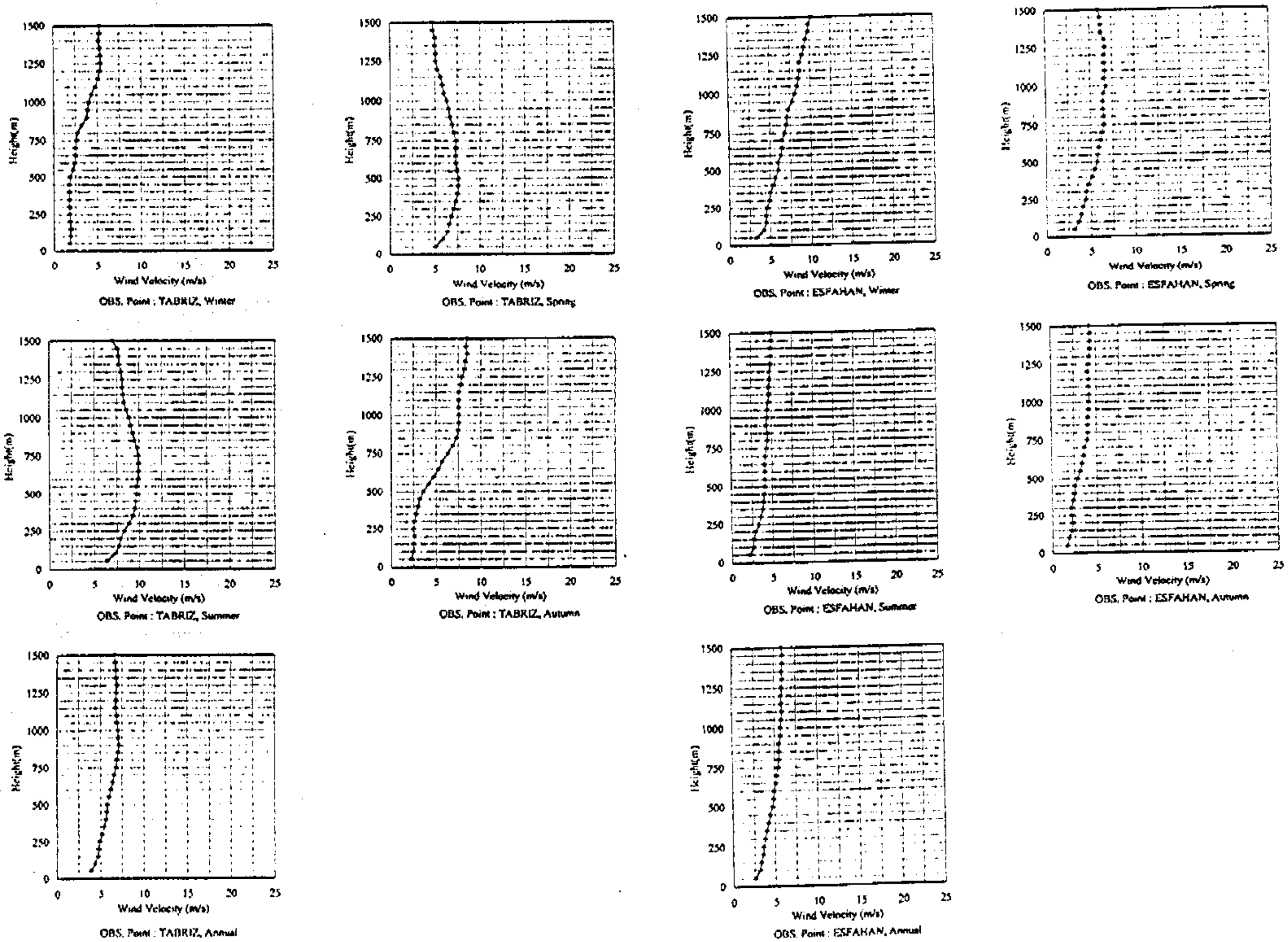


Fig. 5.3.4 Upper Layer Wind velocity - Seasonal and Annual Average

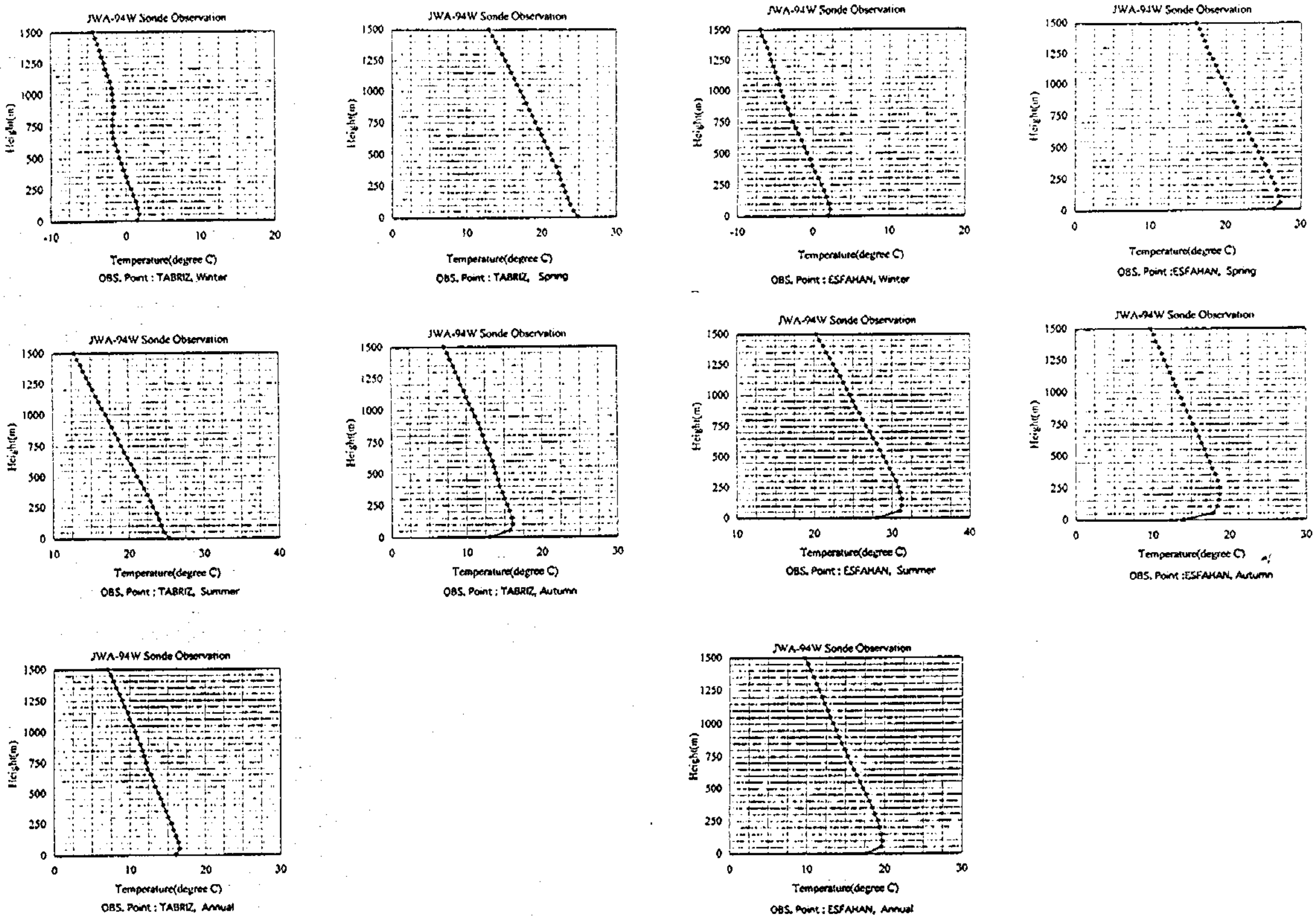


Fig. 5.3.5 Upper Layer Temperature - Seasonal and Annual Average

Atmospheric stability of day time was very unstable in many cases. Especially, in spring and summer, it was unstable even in the upper layer. It is favorable for diffusion of air pollutants. Many inversion layers caused by radiation cooling had been observed near the ground level at night at both power plants. This inversion layer is not favorable for diffusion of air pollutants. The inversion layers near the ground level were stronger at Esfahan than at Tabriz. The Esfahan power plant is located in a small basin where low-temperature air can be accumulated. Especially, in a condition with easterly or southerly weak surface wind, the ground inversion layer appears predominantly. When upper layer easterly wind extends its strength to the ground level, low-temperature air mass accumulated in the small basin flows out to the western area and the upper layer air mass fills up the basin. Accordingly, the ground inversion layer disappears temporarily.

5.4 Surface Observation

5.4.1 Observational Results

Observation results on wind direction, wind speed, temperature, solar radiation, and net radiation monitored inside the power plants at Tabriz and Esfahan, and data on wind direction and wind speed monitored at three air monitoring stations each around the power plants are compiled by the local computer in Tehran and summarized here in **Tables 5.4.1, Fig. 5.4.1** and **5.4.2** (wind direction and wind speed) and in **Table 5.4.2** and **Fig. 5.4.3** (temperature, solar radiation and net radiation).

Table 5.4.1 Surface Meteorology Observational Results (Wind direction and speed)

Observational Location		Main wind direction	Wind Speed (Monthly avarage)	Calm (%)
Tabriz	Power Plant	ENE	5.8m/s in July '98 and 2.5m/s in Jan.'99	0.9
	Baranloo	NE	5.5m/s in July '98 and 1.8m/s in Dec. '98	3.3
	Mayan	NE,ENE	6.5m/s in July '98 and 2.9m/s in Jan. '99	0.6
	Qaramalek	E~ESE	3.6m/s in July '98 and 1.7m/s in Jan. '99	1.4
Esfahan	Power Plant	S~SE	3.7m/s in June '98 and less than 2m/s in other months	7.0
	Gholshar	W~WSW	Less than 2m/s from July '98 to Jan. '99 and less than 2.5m/s in other months	4.6
	Kaveh	—	Less than 2m/s from Sept. '98 to Jan. '99 and 2~3m/s in other months	3.1
	Shariati	W~WSW	3.5m/s in June '98 and les than 2m/s from July '98 to Jan. '99	9.1

Note : Calm: wind velocity less than 0.4m/s, indicated % of calm hours in a month

Table 5..4.2 Surface Meteorological Observational Results
(Temperature, Solar radiation and Net radiation)

	Temperature	Solar Radiation	Net Radiation
Tabriz	The highest temperature : 39.2℃ in Aug. '98 The lowest temperature : -8.7℃ in Feb. '99 Monthly average highest : 26.8℃ in June '98 Monthly average lowest : 0.8℃ in Jan.'99	Monthly average highest : 1.16 MJ/h in June '98	Monthly Average lowest : 0.00 MJ/h in Dec. '98
Esfahan	The highest temperature : 39.8℃ in July. '98 The lowest temperature : -6.3℃ in Jan. '99 Monthly average highest : 32.3℃ in June '98 Monthly average lowest : 3.5℃ in Jan.'99	Monthly average highest : 1.45 MJ/h in June '98	Monthly average lowest : 0.01MJ/h in Dec. '98

In Tabriz, the high wind frequency occurred mainly in the easterly (E) direction. Wind was strong in July 1998 and it was weak in Oct. 1998 to Jan. 1999. In Esfahan, there were not distinctive features of wind direction, and the wind was mainly weak.

5.4.2 Evaluation

Frequency by the wind speed class is shown in **Fig. 5.4.4** and the atmospheric stability frequency is given in **Fig. 5.4.5.**

The highest frequency by the wind speed class was 1.0 to 1.9 m/s at Baranloo and Qaramalek in Tabriz, and at all the four stations in Esfahan. The calm frequency was somewhat high at the above-mentioned stations. The weak wind is considered as the results from the above. The highest frequency observed at Mayan was more than 6.0 m/s, which was distinctive there. The atmospheric stability was high frequency of dD and nD at Tabriz power plant and Mayan in Tabriz. Baranloo and Qaramalek in Tabriz, and three stations in Esfahan have high frequency of strong stable conditions(G).

As the results given above, the meteorological conditions at Baranloo and Qaramalek in Tabriz, and all the four staitons in Esfahan tend to cause the less possibility of air pollutant dispersion with the weak wind and the high frequency of stable conditions.

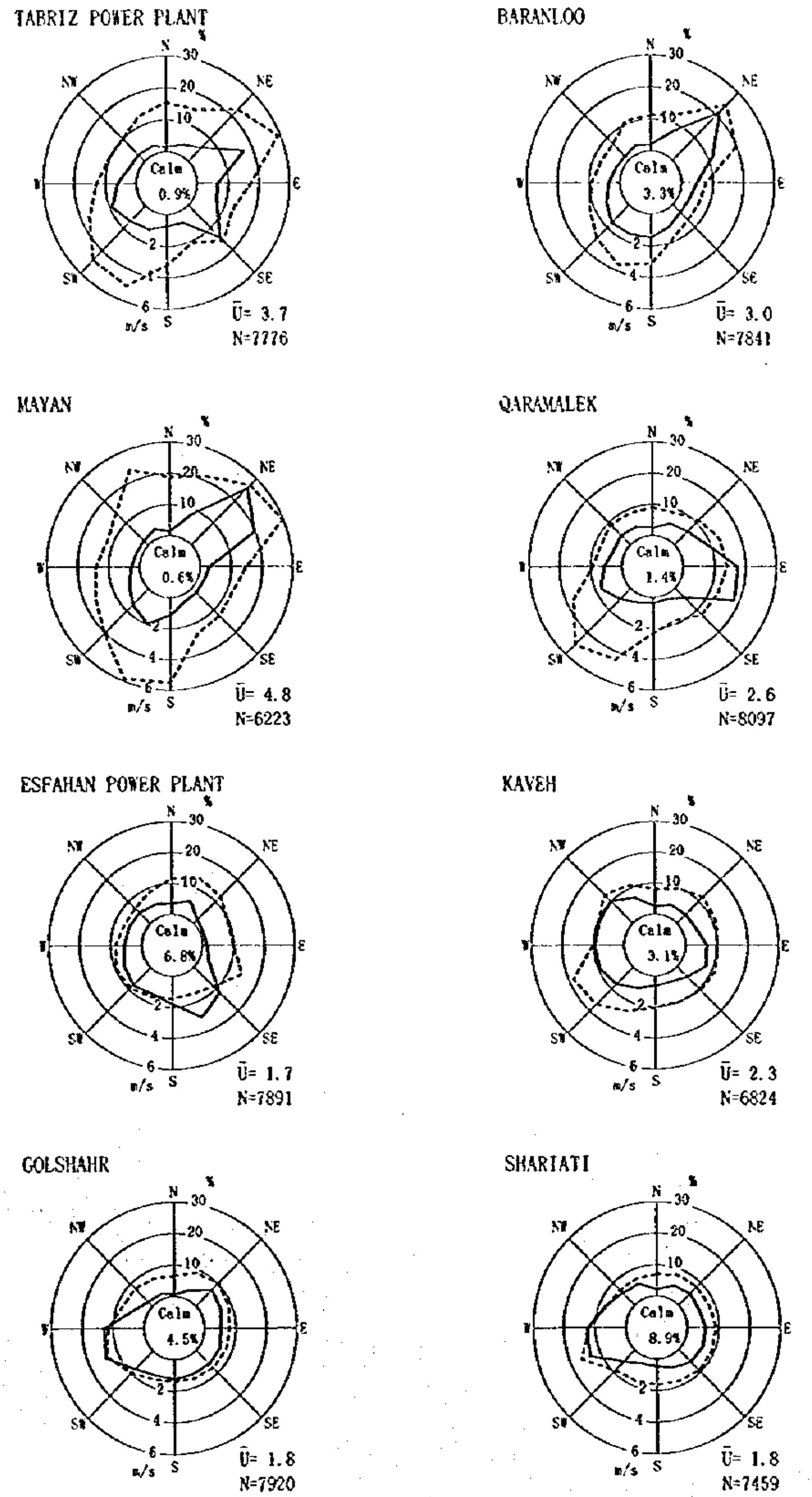


Fig. 5.4.1 Wind Rose Diagram (Annual)

——— Wind Direction Frequency
------- Wind Speed Average
Calm ≦ 0.4 m/s

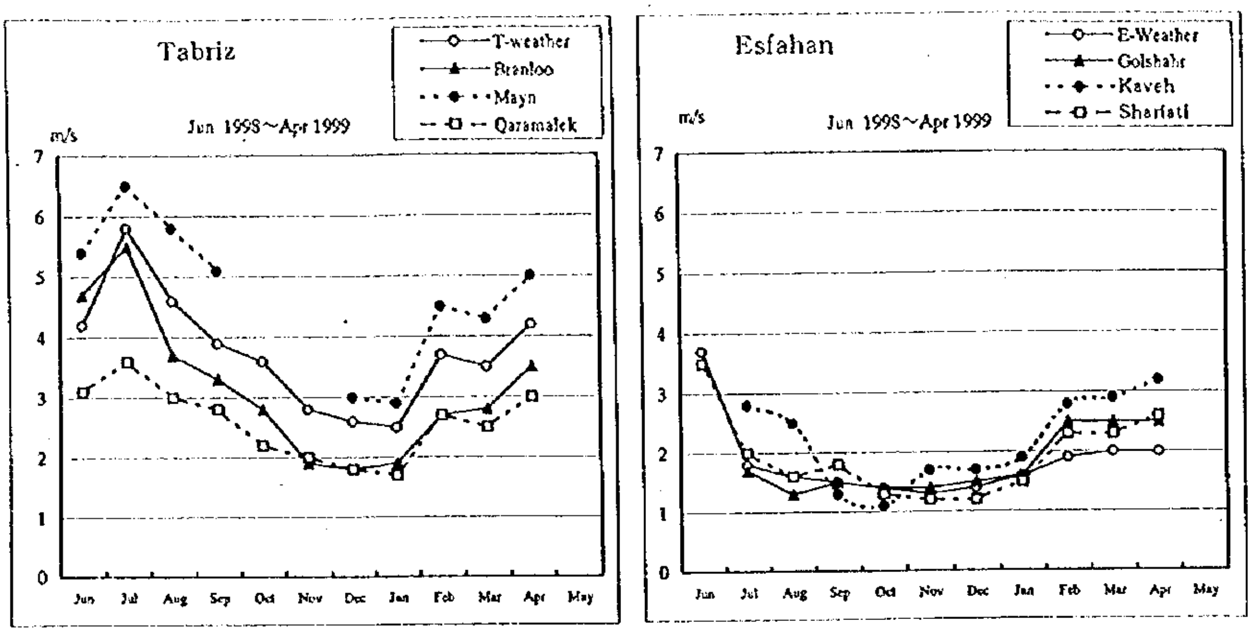


Fig. 5.4.2 Monthly Changes of Wind Speed

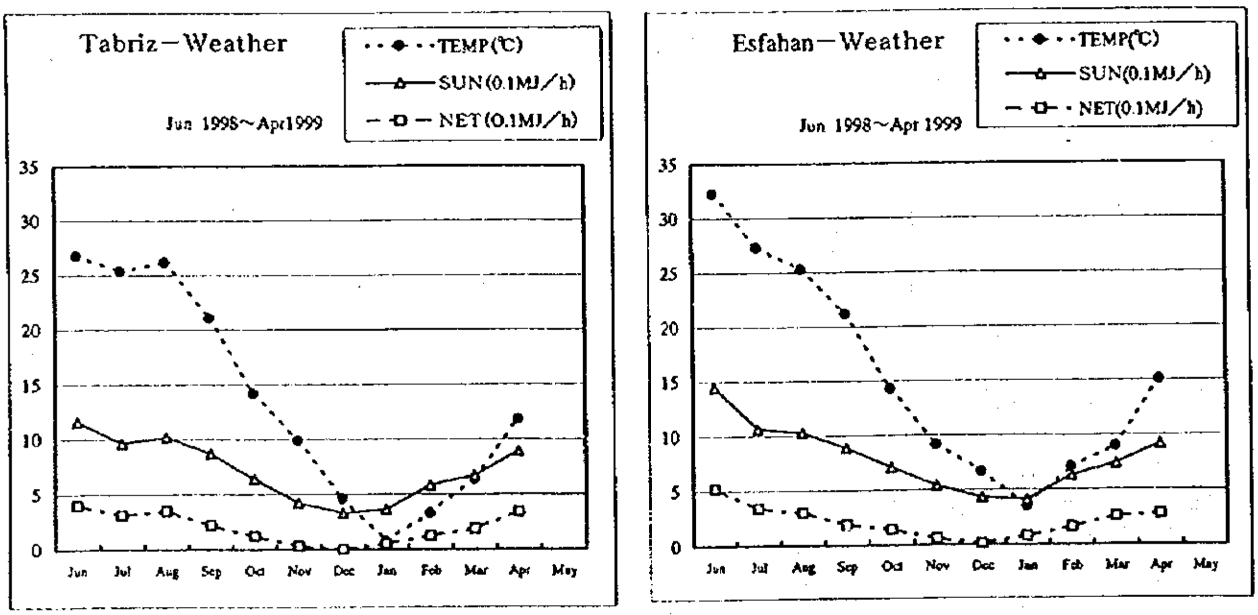


Fig. 5.4.3 Monthly Changes of Temperature,Solar Radiation and Net Radiation

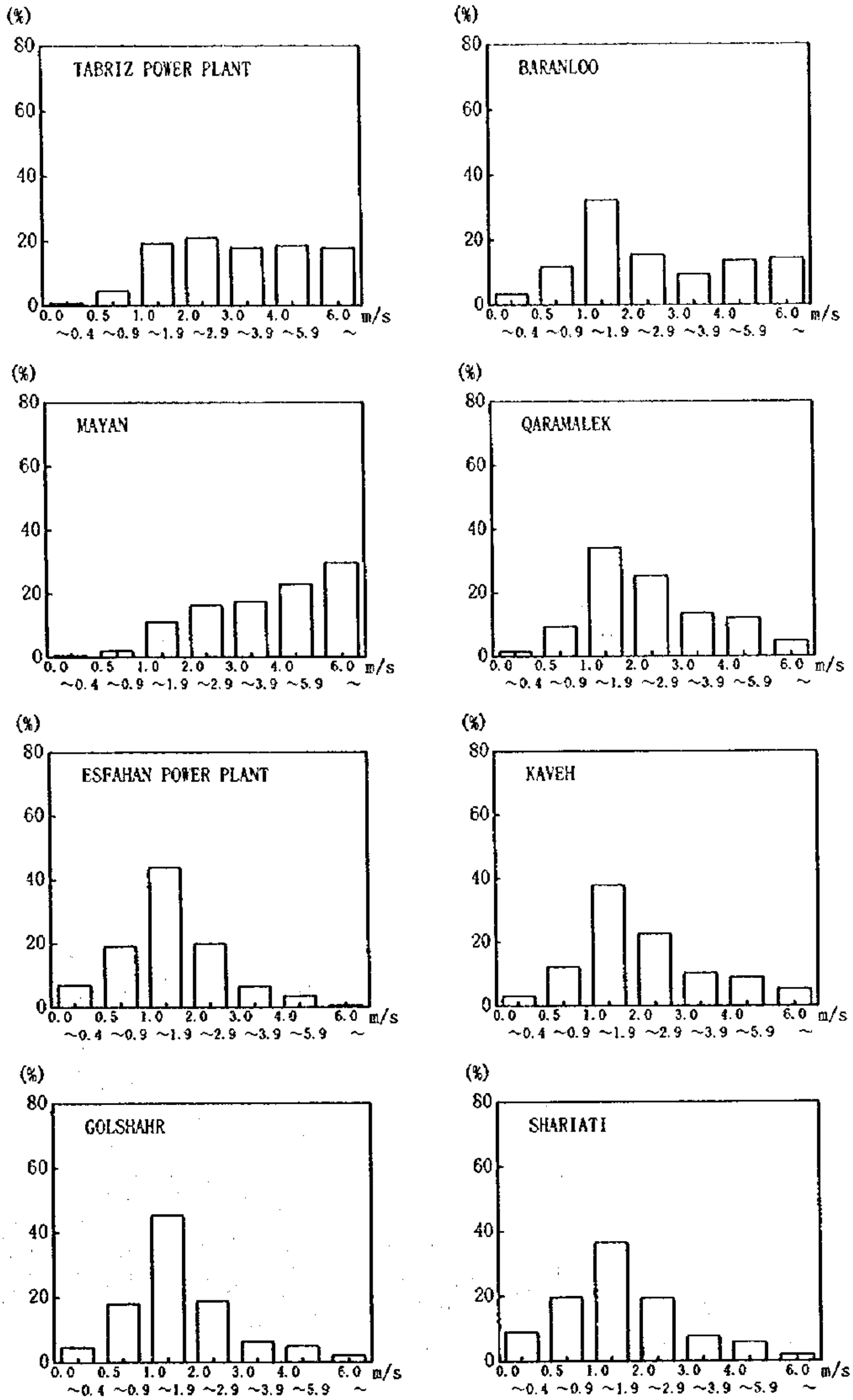


Fig. 5.4.4 Wind Speed Frequency (Annual)

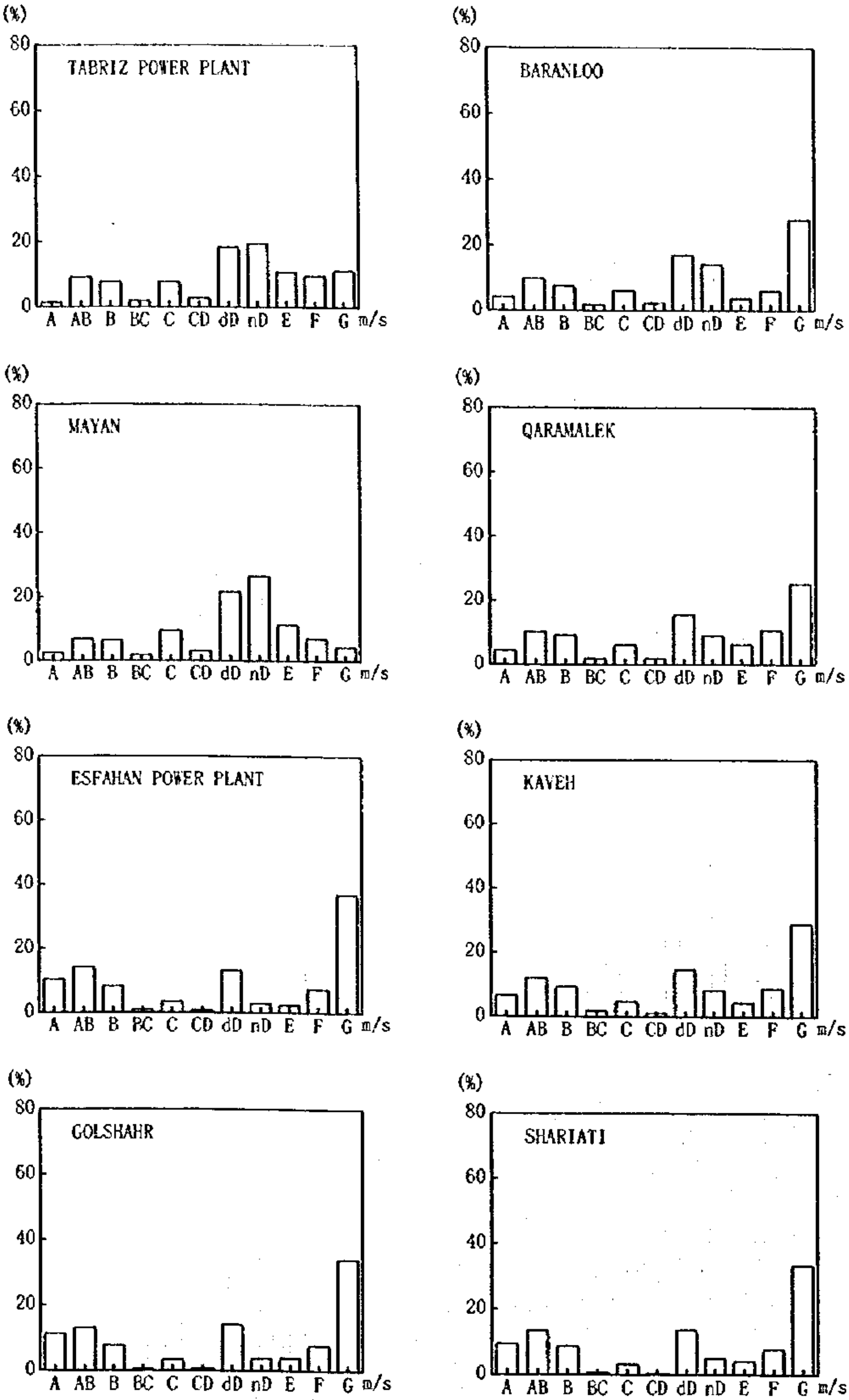


Fig. 5.4.5 Stability Frequency (Annual)